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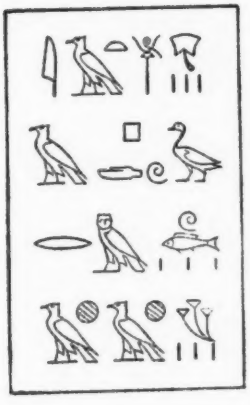

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THE JOURNAL OF WILDLIFE MANAGEMENT

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NESTING STUDIES OF CANADA GEESE ON THE HANFORD RESERVATION, 1953–56[1]

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Studies of the nesting of Great Basin Canada geese (*Branta canadensis moffitti*) on the Hanford Reservation have been conducted since 1950, in co-operation with the Washington State Department of Game. These studies were conducted to determine the population density, nesting habits, and various aspects of productivity of the population of geese that inhabit the Hanford Reservation, where they are exposed to low levels of radioactive contamination. This paper summarizes the nesting surveys of 1953 through 1956 and includes histories of 1,032 nests.

DESCRIPTION OF STUDY AREA

The Atomic Energy Commission Hanford Works Reservation in southeastern Washington includes approximately 57 miles of the Columbia River. The lower 40 miles contain 20 islands, 18 of which are used as nesting sites by Canada geese. These 18 islands, which were included in our surveys, are in two groups of nine islands each (Fig. 1). The upper group averages 380 feet above sea level, compared to about 340 feet for the lower group.

The islands vary in size from 3 to 300 acres. The smaller ones are coarse gravel bars, while the larger ones formerly supported farms. The soils have been classified as riverwash, dune sand, and sandy loam (Kocher and Strahorn, 1919). Sand and clay loam bluffs, which rise 200 feet above

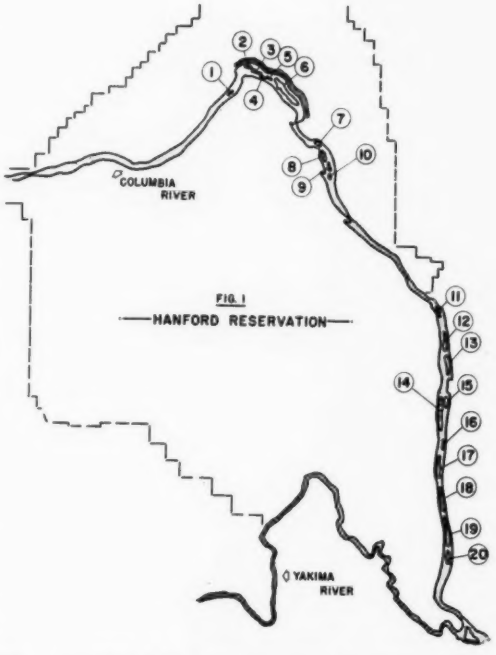

FIG. 1. Map of Columbia River, Hanford Reservation, showing islands used as nesting sites by Canada geese.

the north river bank for 5 miles in the region of the upper group of islands, were also utilized as nesting sites by a few geese but are excluded from the present report.

The study area lies in the Upper Sonoran Life Zone. Annual rainfall averages 6.18 inches, with approximately 42 per cent of it occurring during November, December, and January. An additional 40 per cent occurs during the Canada goose nesting period, February through May.

The Columbia River in this area has an average velocity of 2 miles per hour (about 42 million g.p.m.); during the spring freshet

[1] This paper is based on work performed under Contract No. W-31-108 Eng-52 between the General Electric Company and the U.S. Atomic Energy Commission.

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period it increases to 4 miles per hour (about 180 million g.p.m.). At that time the islands are inundated to varying degrees and subjected to the scouring action of the water.

SURVEY METHODS

The first pairing of geese occurred during the first week of February, and nesting surveys were initiated during the first week of April of each year, with subsequent visits at 7- to 10-day intervals thereafter. One per cent of the nests were situated on natural shelves of the bluffs, usually 10 to 20 feet above the water level. Observations of such nests were made with the use of binoculars from a boat. The remaining nests were on the islands. Two biologists walked the islands, flushed the geese, and counted territorial pairs. As each nest was found for the first time, a numbered willow stake 6 to 8 feet long was placed in the ground a short distance from the nest, with the number facing toward the nest. This provided nest identification and aided in location of the nest on subsequent visits. Numbers of territorial pairs, clutch size, stage of incubation, cover type, and other information related to the fate of the nest and eggs were recorded.

TABLE 1.—CANADA GOOSE NESTING DENSITIES, 1953–56

Island No.	Area (Acres)	Density (Nests/Acre)			
		1953	1954	1955	1956
1	7	1.9	1.7	1.7	1.7
2	5	3.2	4.0	3.4	3.8
3	40	0.5	0.5	0.6	0.4
4	3	0.3	0.7	0.3	0.7
5	1	—	—	—	—
6	300	0.3	0.3	0.3	0.4
7	4	0.5	0.5	0.3	0.3
8	30	0.4	0.6	0.4	0.4
9	6	1.7	1.7	1.8	0.8
10	5	0.6	0.4	0.6	0.4
11	20	0.6	0.5	0.4	0.3
12	60	0.2	0.2	0.1	0.1
13	50	0.1	0.04	0.1	0.2
14	300	—	0.01	0.01	0.003
15	20	0.3	0.3	0.2	0.3
16	2	—	—	—	—
17	60	0.4	0.6	0.5	0.5
18	40	0.1	0.1	0.2	0.2
19	200	0.06	0.05	0.03	0.05
20	15	0.3	0.2	0.1	0.4

NESTING SITES AND COVER TYPES

Nesting densities for all islands were fairly constant (Table 1) and suggested maximum utilization of acceptable nest locations. The three islands with the greatest number of nests per acre are of the same general description: 5 to 7 acres in area, exposed cobblestone, gravel and sand, and open stands of *Lupinus, Eriogonum,* and *Salix.* On the largest island, which supported 37 per cent of all nests, a majority of the sites were along the margin of the higher ground or on the several riverwash gravel hummocks that composed the upstream end of the island, rather than in the middle of the island. Thus, as observed by Dow (1943), Kossack (1950), Miller and Collins (1953), Naylor (1953), Williams and Marshall (1937), and Steel, Dalke, and Bizeau (1957), visibility of surrounding terrain appears to be a major factor in selection of nesting sites by Canada geese. It was at nests located in dense cover, from which there was limited visibility, that the only observed instances of predation of incubating females were noted, both of them in 1955.

The presence of mammalian predators was possibly another factor affecting the choice of nesting sites. This was apparently the factor that limited nesting on Island No. 14, which has many of the characteristics of the more successful islands, except that it is separated from the mainland by a short distance of shallow water. Coyote (*Canis latrans*) and raccoon (*Procyon lotor*) tracks were common along its shoreline.

Re-use of nesting sites through several seasons was common, and one instance of two broods being produced in the same nest during one season occurred in 1954. Failure of a nesting attempt at a certain site did not affect its use a year later unless total destruction by predators was the cause of failure. No information was obtained as to whether one particular pair of geese returned to the same nesting site perennially, although a partially albino goose was noted

TABLE 2.—COVER TYPES UTILIZED BY NESTING CANADA GEESE, 1954–56

Year No. of nests	1954 277	1955 256	1956 262	Mean 795
Ryegrass (*Elymus condensatus*)	14%	18%	16%	16%
Lupine (*Lupinus* spp.)	16	13	12	14
Smooth wild rye (*Elymus glaucus*)	17	13	10	13
Yarrow (*Achillea lanulosa*)	4	7	12	8
Willow (*Salix exigua*)	8	7	8	8
Absinthe (*Artemisia absinthium*)	8	5	9	7
Rose (*Rosa Spaldingii*)	5	5	3	5
Sagebrush (*Artemisia tridentata*)	4	5	4	4
Driftwood, debris, or no cover	3	6	5	4
Russian thistle (*Salsola kali*)	4	3	4	4
Eriogonum (*Eriogonum compositum*)	3	3	2	3
Miscellaneous (20 species)	13	14	15	14
Totals	99	99	100	100

at the same general location on one island during four consecutive nesting seasons.

Vegetational cover types that were associated with nest sites during the last three seasons are summarized and listed in order of frequency in Table 2. Apparently the cover type depends largely upon availability and is incidental to other factors influencing the selection of a nesting site. A similar observation was expressed by Steel *et al.* (*ibid.*) concerning the use of muskrat houses for goose-nesting sites in Idaho.

An attempt was made in 1951 to encourage nesting on an island (No. 14) that supported no nests during the previous season. Seventy-five nesting platforms similar to that shown in Fig. 2 were erected on this island, and six more were installed on an adjacent island (No. 15) that had a nesting density of 0.3 nest per acre. In the succeeding six nesting seasons, none of these platforms were used, although geese nested on the ground within 6 feet of them. Artificial nesting sites have been used by Canada

FIG. 2. Photo of nesting platform erected on Island No. 14.

geese in other areas of the state (Yocom, 1952).

NESTING PERIOD

The nesting period is defined as the time between the initiation of the earliest successful nest and the termination of the last nest. The starting date was determined by subtracting 5 weeks from the date of the first hatching, on the assumption that 1 week was required for the laying of the clutch and 4 weeks for incubation. The nesting period for Canada geese at Hanford was 12 weeks in 1953, 11 weeks in both 1954 and 1955, and 10 weeks in 1956. The average nesting period of 11 weeks was essentially the same as that found in the Klamath Basin by Miller and Collins (*op. cit.*), and greater than that observed by Steel *et al.* (*op. cit.*) in Idaho, Dow (*op. cit.*) at Honey Lake, California, Kossack (*op. cit.*) in Illinois, or Williams and Marshall (*op. cit.*) at Bear River, Utah. It is assumed that greater uniformity would exist if similar climatic conditions prevailed at all locations.

Generally, most nesting started during the third and fourth weeks of March, and the peak of hatching occurred during the last week of April and first week of May. This is approximately the same as that observed by other investigators (*op. cit.*). The 1953 nesting period started one week earlier than in 1954, and two weeks earlier than in 1955 and 1956 (Fig. 3). This is believed to be the result of influences accompanying average daily temperatures above the seasonal norm. Meteorological data from the Hanford Meteorology Station showed a period of unprecedented warmth during January and early February of 1953. During the first 39 days of 1953, there were 29 days in which the temperature did not get as low as 32°F. Twenty-three of these days (January 16 through February 7) occurred in succession. The over-all average temperature of 41.2°F. for the month of January was 13.4° above normal. Comparison of the average daily temperatures and start of nesting in all years of this study indicates that goose nesting in the Hanford area starts with the occurrence of average daily temperatures above 40°F. Measurements of solar radiation at the Hanford Meteorology Station during 1955 and 1956 averaged 250 gram calories per square centimeter during the period when nesting started during these years.

FATE OF NESTS

During surveys prior to 1953, several nest-sized depressions in the earth, surrounded by goose tracks, were classified as "nests still under construction." From the start of nesting activity in 1953, all such "nests" were marked; none became active. The possibility that these represented one of several sites excavated prior to selection of the final nest location appears remote, because they were found in a ratio of one "dummy" nest per thirty-five active nests.

The fate of nests in each year is summarized in Table 3. The nesting density on the islands did not change appreciably during the study, nor did the ratio of paired to unpaired geese change noticeably. Desertion decreased in 1955 for no obvious reason. Crowding was not a major factor in desertion, as there were ample nesting sites and abandonment occurred almost equally among crowded and isolated nests. No intraspecific strife was noted, nor did nesting densities appear to be great enough to induce desertion, as observed by Naylor (*op. cit.*) and Miller and Collins (*op. cit.*). The 9 to 13 per cent desertion observed is similar to that found by other investigators.

During 1954, the interval between surveys was changed from 7 to 10 days, and, in an attempt to evaluate desertion caused by human disturbance, Island No. 8 was not visited between the first and last surveys. The reduction in disturbance did not result in a decrease in desertion. In 1955 when the 7-day interval was resumed, desertion declined 3 per cent, then increased 4 per cent in 1956.

Nests were classed as "destroyed" when there was evidence of molestation, such as scattered shell fragments from destroyed eggs, or scattered down. The possibility that desertion might have preceded destruction was considered likely when the nest contained little or no down.

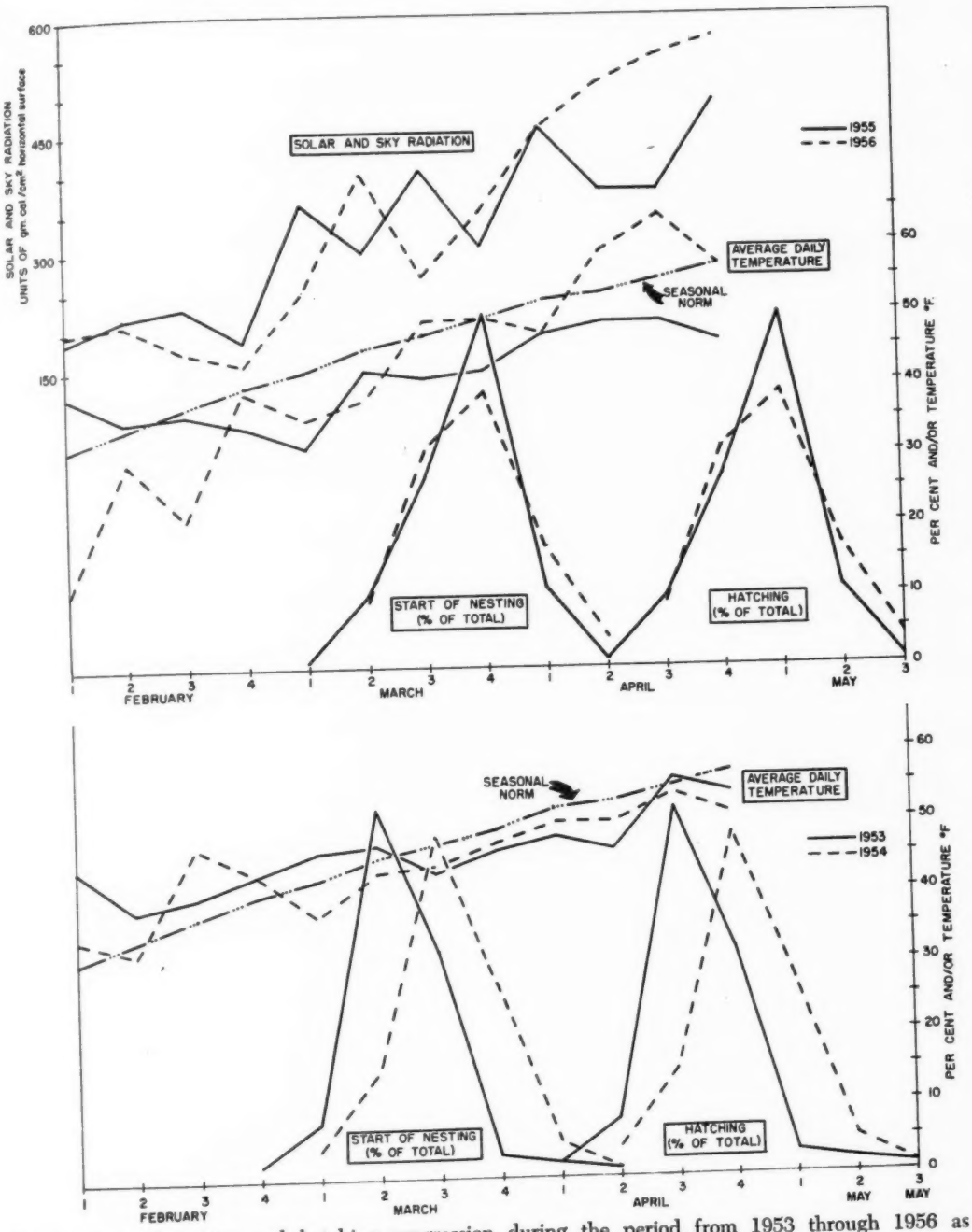

FIG. 3. Start of nesting and hatching progression during the period from 1953 through 1956 as compared to average daily temperature and solar and sky radiation.

Although magpies (*Pica pica*) were not an important predator of goose nests in Montana (Geis, 1956), our observations leave little doubt as to their importance in this area. Destruction was principally caused by magpies, as evidenced by many instances of goose egg shells scattered around favorite perching spots, and beneath

TABLE 3.—FATE OF NESTS OF CANADA GEESE ON HANFORD RESERVATION, 1953–56

Year	1953	1954	1955	1956
No. of Nests	246	273	254	260
Successful	71%	73%	78%	62%
Destroyed	16	11	13	11
Deserted	12	12	9	13
Chilled or infertile	1	3	0.4	2
Flooded	—	1	—	13
Unknown	—	0.4	—	—
Totals	100	100	100	101

magpie nests and nesting cover. During 1953, a relatively isolated population of approximately 30 magpies destroyed all 23 nests on one island. Prior to the 1954 goose nesting season, poisoned bait was distributed over the island and an extensive magpie kill was obtained. Few magpies were seen on the island during the following nesting season, and no goose nests were destroyed by magpies. No poisoning was done in 1955, and destruction on this island increased. The greatest destruction rate occurred among nests near rose bushes (*Rosa Spaldingii*). Since thickets of these bushes are favorite nesting and perching sites for magpies, goose nests under such cover were more likely to be observed and destroyed by them. Nests in yarrow (*Achillea lanulosa*), Russian thistle (*Salsola kali*), and sagebrush (*Artemisia tridentata*) cover had the lowest destruction rate.

Destruction by mammals was minor. The threat of destruction or past experience may have been influential in the low usage of Island No. 14. No destruction was attributed to ring-billed gulls (*Larus delawarensis*), or California gulls (*L. californicus*), although large colonies of them nested on two of the islands in the study area.

The influence of nest markers and human activities upon nest predation, as shown in duck nest studies by Hammond and Forward (1956), was not evaluated, since normal destruction rates were not determined in earlier surveys of this population (Hansen and Oliver, 1951).

Fifteen nests failing to hatch were classified as "chilled or infertile" after being incubated for 30 to 44 days before abandonment. In 1956, additional visits were made to five such nests after the normal nesting season to determine how long the geese would incubate infertile or addled clutches of eggs. Two nests were deserted after being incubated a minimum of 35 and 49 days, and the other three were flooded after being incubated at least 51 days. All but one of the 15 nests termed "chilled or infertile" contained fertile eggs in which embryos had died at various stages of development.

Flooding was of minor importance until April 1956, when a premature flood crest of the Columbia River, caused in part by the release of stored water at Grand Coulee Dam, destroyed approximately 12 per cent of the nests.

FATE OF EGGS

Hatchability of 3,947 eggs in 732 successful nests averaged 92 per cent, with little variation during the entire study period (Table 4). Numbers of dead embryos and infertile eggs were as low or even lower than reported in comparable studies at other locations (*op. cit.*). This suggests that the operation of Hanford reactors has had no harmful effect on the fertility of Canada geese.

In studying the possible effect of radioactive contamination on egg fertility, only clutches from successful nests were used in the compilation of the fate of eggs, as the inclusion of nests deserted, destroyed, or otherwise terminated prematurely represents a possible source of error.

Eggs were classified as infertile if the yolk was wholly or partially suspended in the albumen, according to the method of

TABLE 4.—FATE OF EGGS IN SUCCESSFUL NESTS, 1953–56

Year	1953	1954	1955	1956
No. of Eggs	927	1093	1048	879
Hatched	93%	91%	92%	92%
Fertile, unhatched	5	7	6	7
Infertile	2	2	1	1
Missing or broken	0.2	—	1	1
Totals	100	100	100	101

TABLE 5.—STAGE OF DEVELOPMENT OF DEAD EMBRYOS IN EGGS, 1953–56

Age of Embryo	1954	1955	1956
	Per Cent	Per Cent	Per Cent
0–1 week	40	61	59
1–2 weeks	13	12	3
2–3 weeks	10	6	7
3–4 weeks	37	21	31

Kossack (*op. cit.*). Fertile eggs that failed to hatch were broken to determine stage of development, unless activity inside the egg indicated a live embryo. Such eggs were marked and placed in another nest of pipped eggs, where they usually hatched if the embryo had not been weakened from chilling or other causes. The first and last weeks of embryonic development of the gosling were evidently the most critical periods, according to this study (Table 5).

Eight dead young were found in hatched nests. This is presumably the result of individual weakness, chilling while wet, delayed hatching, crushing by parent birds, or a combination of these factors. One live gosling, evidently an example of delayed hatching, was found in a nest previously hatched and deserted by the brood, but it died shortly after being found.

CLUTCH SIZE

Average clutch size varied from 5.3 in 1953 and 1955 to 5.5 in 1954 and 1956, during which years a slight trend was noted toward larger clutches (Fig. 4). An extreme clutch size of 13 eggs was found in 1953 and is believed to represent a true clutch of one goose. Nine of these eggs hatched, two were infertile, and two contained embryos that died during the first week of development. Hatching percentages of various clutch sizes are shown in Table 6. Comparison of smaller clutches of one to four eggs, or larger ones of seven to nine eggs, shows a lower hatching percentage among large clutches, although during 1953 the three groups were equally successful.

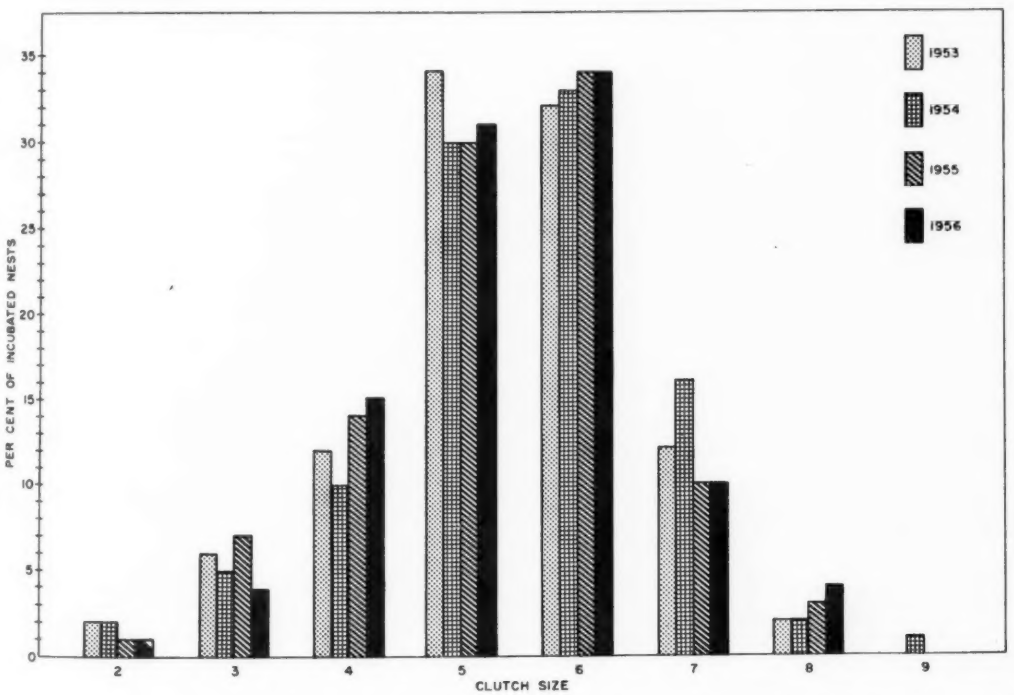

FIG. 4. Clutch size frequencies of incubated nests of Canada geese at Hanford during the period from 1953 through 1956.

TABLE 6.—COMPARATIVE HATCHING PERCENTAGE OF VARIOUS CLUTCH SIZES, 1953–56
(numbers in parentheses indicate size of sample)

Clutch Size	HATCHING PERCENTAGE				
	1953	1954	1955	1956	Mean
1–4	93 (30)	92 (36)	92 (46)	97 (29)	93
5–6	94 (99)	91 (122)	93 (125)	93 (110)	93
7–9	94 (22)	89 (41)	88 (26)	86 (20)	89

TERRITORIAL PAIRS

Territorial pairs were defined as pairs of geese that were observed to be closely associated with a small area and that retained their identity in relation to other geese. Females that flushed from the nest and were joined by their mates made up a considerable proportion of this category. Geese that occurred in small flocks of three or more were assumed to be nonbreeders and were not included in the count. Although on several instances pairs were observed to "break off" from such groups when put to flight, they were not counted as territorial. The number of unemployed geese observed during each year varied from 134 to 149.

Counts of territorial pairs were made during the first three surveys of each year. During this period, before most nests hatched, the number of pairs counted remained constant and consistently greater than the number of nests found. The discrepancy was presumably caused by counting pairs that were unsuccessful in nesting attempts of the current season, as suggested by Naylor (*op. cit*), Naylor and Hunt (1954), and Geis (*op. cit.*). Comparison of results during the 4 years of observation (Table 7) shows an average population of 7.6 territorial pairs per river mile in the Hanford area. The remarkable constancy of population density and nesting density on the islands suggests saturation of the study area by the geese. The number of young produced by this population is included in the table for convenient comparison.

TABLE 7.—BREEDING POPULATION AND PRODUCTION OF YOUNG, 1953–56

	1953	1954	1955	1956
Territorial pairs				
Total	304	299	306	308
Pairs per nest found	1.2	1.1	1.2	1.2
Pairs per river mile	7.6	7.5	7.7	7.7
Young produced				
Total	864	983	964	806
Per successful nest	4.9	5.2	4.9	5.0
Per river mile	22	25	24	20

BROOD DATA

A total of 134 week-old broods ranging from 1 to 16 goslings was observed during the 4 years of study. Comparison of average brood size with clutch size and young produced during the various years showed an intermingling of broods at an early age. Further evidence of this was noted among older broods, many of which contained goslings of two or more distinct age groups. This prevented accurate determination of gosling mortality on the basis of brood-size decline.

We estimate that the breeding population of approximately 300 territorial pairs produced from 810 to 980 young per season, representing an estimated one-eighth of the total Canada goose production in the State of Washington (Oliver, pers. comm.).

SUMMARY

Nesting studies of Canada geese were conducted on the Hanford Reservation in southeastern Washington during 1953 to 1956. Complete histories were made on 1,032 nests. Nesting density on the islands varied from 0.003 to 4.0 nests per acre. Selection of cover type was apparently incidental to other factors, such as availability and visibility from nest. Seventy-one per cent of the nests hatched, 13 per cent were destroyed by predators, 11 per cent were deserted, and 3 per cent were flooded. Hatchability of eggs in successful nests

averaged 92 per cent; 6 per cent contained dead embryos and 2 per cent of the eggs in successful nests were infertile. A majority of the dead embryos were found to be in the first and fourth weeks of development. Average clutch sizes were 5.3 in 1953 and 1955, and 5.5 in 1954 and 1956. This resulted in production of 4.9 young per nest in 1953 and 1955, 5.2 young per nest in 1954, and 5.0 young per nest in 1956. Peaks of hatching occurred from the third week of April to the first week of May, and varied with the average daily temperature during the 4 years. The peak was usually near the last week of April. Total length of the nesting season was 12 weeks in 1953, 11 weeks in 1954 and 1955, and 10 weeks in 1956. The breeding population of approximately 300 territorial pairs produced an estimated 810–980 young per season. No adverse effect on the adult geese, their eggs, or young by Hanford reactor operations was noted.

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EFFECT OF 2,4–D ON ABUNDANCE AND FOODS OF POCKET GOPHERS

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Sound management of rangelands in the western United States may not be fully realized until the influences of small rodents are more clearly understood. This is particularly true in mountainous areas where pocket gophers (*Thomomys talpoides*) are numerous. Although several studies have been designed to investigate the effect of pocket gophers on rangeland (Ellison, 1946; Tryon, 1947; Kalmbach, 1948; Moore and Reid, 1951; Ellison and Aldous, 1952), the net influence of gopher activity is not yet clear. Currently, there are two broad viewpoints, each supported to a degree by research findings. One contends that pocket gophers have little effect on rangeland, since

FIG. 1. Typical weedy grassland on Grand Mesa.

removal of the animals from experimental plots resulted in no significant improvement in the plant cover (Ellison, *op. cit.*; Kalmbach, *op. cit.*; Ellison and Aldous, *op. cit.*). The other, widely held by ranchers and land administrators, is that gophers are a detriment to rangeland and its improvement and should be controlled. Studies by Moore and Reid (*op. cit.*) lend credence to this view. However, effective and economical control methods have yet to be developed and tested on extensive areas.

The possibility that spraying rangeland with 2,4–D (2,4–dichlorophenoxyacetic acid) might reduce pocket gopher populations was noted by Cummings (1948) and Kalmbach (1950) when inspecting experimental plots sprayed by the Forest Service in western Colorado. They observed that gopher mounds were less abundant on sprayed plots than on adjacent untreated areas. The present study, as a follow-up on their observations, was designed to provide more conclusive evidence of the effect of spraying with 2,4–D on gopher populations and gopher food habits.

The plant nomenclature cited below follows Harrington (1954).

STUDY AREA

Grand Mesa, in west-central Colorado, was selected for study because large areas of weedy rangeland with dense populations of gophers were being sprayed with 2,4–D by the Forest Service. Grand Mesa has an average elevation of 10,300 ft. and an average annual precipitation of about 30 in., most of which falls as snow. The shallow, fertile soils are of volcanic origin. Groves of Engelmann spruce (*Picea engelmanni*) and alpine fir (*Abies lasiocarpa*) are scattered throughout large parks and meadows. Pocket gophers are abundant only in nonforested areas.

Rangelands on Grand Mesa are generally in fair to poor condition (Fig. 1). Herbage production averages 700 lb. (air dry) per acre, of which about 530 lb. are produced by forbs, including dandelion (*Taraxacum officinale*), Rydberg penstemon (*Penstemon rydbergii*), agoseris (*Agoseris* spp.), western yarrow (*Achillea lanulosa*), and sneezeweed (*Helenium hoopesii*). Grass and sedge production averages about 170 lb. per acre and consists primarily of Letterman needlegrass (*Stipa lettermani*), bluegrass (*Poa* spp.), sedges (*Carex* spp.), subalpine needlegrass (*Stipa columbiana*), and slender wheatgrass (*Agropyron trachycaulum*).

In an attempt to improve the condition of these rangelands, the Forest Service sprayed about 2,000 acres with 2,4–D between July 6 and July 19, 1956. The herbicide was applied by airplane at the rate of 3 lb. acid equivalent per acre in a butyl-ester formulation with a diesel oil carrier. Other areas to the west and east were sprayed in 1955 and 1957, respectively.

Prior to spraying in 1956, ten study plots, 200 ft. square, were established to evaluate the effect of the herbicide on vegetation, gopher populations, and gopher food habits. Five plots, designated as spray plots (S-1 to S-5), were located in the area to be sprayed, and five others, designated as control plots (C-1 to C-5), were in an area that would not be treated. An attempt was made to locate these plots in areas of similar vegetation and gopher abundance. Cattle were excluded from these treated areas during the year in which they were sprayed and during the following growing season. Grazing was not restricted on control plots. Differential grazing on spray and control plots probably had little effect on the study. Cattle exclosures on Grand Mesa show little change as a result of 15 years' protection from grazing.

Records of ground cover, herbage production, gopher abundance, and gopher food habits were taken just prior to spraying in 1956. In 1957, because of an abnormally heavy snow pack and delayed plant development, observations were made 3 weeks later than in 1956. Plots S-4 and S-5, located on the eastern edge of the 1956 spray area, were inadvertently sprayed again in 1957 before records of vegetation and gopher numbers were obtained.

POCKET GOPHER POPULATIONS

To provide an index to the relative abundance of pocket gophers in 1956, Macabee traps were set along the 800-ft. periphery of each study plot. Burrows were located by probing at 4-in. intervals, and traps were placed in each burrow found. Traps were left for a 48-hour period and checked twice daily. The number of gophers trapped during that period was used as an index to the population on each area.

In 1957 this procedure was repeated, using approximately the same trap lines. Exploratory work prior to this study showed that complete removal of gophers from larger areas (up to 4.5 acres) had little or no effect on population numbers the following year.

The total number of pocket gophers trapped on control plots increased from 101 in 1956 to 110 in 1957. In comparison, 117 animals were taken from the spray plots before treatment in 1956, but only 15 were captured in 1957 (Table 1). This represents a reduction of 87 per cent. Analyses show no significant differences between numbers of gophers trapped from the control areas in 1956 and 1957, or between the numbers taken from the spray plots before treatment in 1956 and those from the control areas either year. The reduction in numbers from 1956 to 1957 on the treated area was significant (P=0.01).

To verify these findings further, an additional method was devised to compare the

TABLE 1.—NUMBER OF POCKET GOPHERS TRAPPED ALONG PERIPHERY OF STUDY PLOTS ON GRAND MESA

Plot	Year	C-1	C-2	C-3	C-4	C-5	Totals
CONTROL	1956	22	13	18	25	23	101
	1957	29	31	19	13	18	110
		S-1	S-2	S-3	S-4	S-5	
SPRAYED	1956	31	26	26	23	11	117
	1957	2	2	4	4	3	15

TABLE 2.—NUMBER OF MOUNDS FORMED BY POCKET GOPHERS IN A 48-HOUR PERIOD

When Sprayed	Transect Length (miles)	NEW MOUNDS	
		No.	No./Mi./Day
July 1956	2.7	87	16
July 1956 and 1957	1.8	47	13
July 1957	2.4	144	30
None (control)	1.9	220	58

populations of gophers on treated and untreated areas. The number of new mounds thrown up by gophers during a 48-hour period was counted on transects 6 ft. wide after the old mounds had been obliterated by a brush drag. These transects, all of which were established within a 3-hour period on October 2, 1957, traversed extensive areas. Results obtained by this method are shown in Table 2.

The number of new mounds within the area sprayed in 1956 was only 28 per cent as great as that on the control area. The difference in gopher numbers on these two areas, as indicated by fresh mounds, was somewhat less than found by trapping. This could have been due to several factors: (1) increased activity of gophers in search of scarcer food; (2) more extensive burrow systems and larger territories because of lower population densities; (3) soil moisture differences between treated and untreated areas; and (4) a more representative index because of the larger area sampled.

The fringe area sprayed in 1956 and 1957 had nearly the same number of new mounds as the area sprayed in 1956. The area sprayed in July 1957 had only 52 per cent as many mounds as the control area. This suggests that gopher numbers may have been affected within 3 months after spraying.

EFFECT OF HERBICIDE ON VEGETATION AND GROUND COVER

The production of individual plant species was estimated by the "weight estimate" method (Pechanec and Pickford, 1937) on twenty 2½-square-ft. plots within each 1-acre study area. These estimates were then adjusted to compensate for moisture content and for consistent error of estimate as determined from clipped check plots. Ground cover was sampled on each acre by means of five 100-ft. line transects. Observations were made at 1-ft. intervals, following the procedure described by Parker (1951). Sedges are included with grasses for the purpose of discussion.

Analyses of herbage production data for 1956 and 1957 show a significant reduction in perennial forbs (P=0.01) and an increase in grasses (P=0.05) on the sprayed plots

TABLE 3.—AVERAGE HERBAGE PRODUCTION ON SPRAY AND CONTROL PLOTS IN 1956 AND 1957

Plants	SPRAY PLOTS		CONTROL PLOTS	
	1956	1957	1956	1957
FORBS	(Pounds air-dry herbage per acre)			
Perennials				
Taraxacum officinale	184	17	180	103
Penstemon rydbergii	51	6	178	172
Achillea lanulosa	26	4	53	34
Agoseris spp.	25	tr.	19	14
Helenium hoopesii	24	1	67	39
Stellaria sp.	20	2	10	15
Geum triflorum	17	tr.	46	49
Thlaspi sp.	6	—	5	4
Erigeron sp.	6	—	2	tr.
Viola spp.	5	3	1	2
Eriogonum neglectum	5	tr.	0	0
Solidago sp.	3	4	26	28
Lathyrus leucanthus	1	1	6	7
Lupinus spp.	tr.	—	19	12
Others (16 species)	23	29	37	32
Annuals				
Polygonum douglasii	4	46	3	18
Chenopodium sp.	tr.	4	tr.	2
Collomia linearis	—	2	—	8
Totals	400	119	652	537
GRASSES				
Stipa lettermani	66	118	42	49
Carex spp.	30	41	34	42
Bromus spp.	22	24	1	5
Poa spp.	22	24	23	13
Agropyron trachycaulum	18	23	11	4
Stipa columbiana	17	25	1	3
Trisetum spicatum	10	9	7	9
Danthonia intermedia	8	5	3	1
Festuca ovina brachyphylla	3	2	13	10
Others (4 species)	2	1	2	2
Totals	198	272	137	138

FIG. 2.

FIG. 2. Rangeland on Grand Mesa 1 year after treatment with 2,4–D. Forbs and gophers were greatly reduced in this area.

but no real change on control plots (Table 3). Production of perennial forbs on sprayed plots declined from 396 lb. per acre in 1956 to 67 lb. in 1957, a reduction of 83 per cent. Grasses, on the other hand, produced 74 lb. (37 per cent) more herbage per acre 1 year after spraying (Fig. 2). Total herbage production declined 207 lb. per acre or 35 per cent on sprayed plots compared with 114 lb. or 14 per cent on control plots. Variations in forb production similar to those on control plots between 1956 and 1957 are apparently common in this type and probably result from both temperature and moisture conditions during the plant-growing season.

Spraying also greatly altered the composition of plant cover. In 1956, forbs accounted for 67 per cent of the total herbage produced, while in 1957 they comprised only 30 per cent. Common dandelion was drastically reduced, but Letterman needlegrass increased in production after spraying.

Transect records (Table 4) show that changes in plant cover were essentially the same as those for production. On sprayed areas the percentage of forbs in the cover was greatly reduced, while percentage of grasses increased. The reason for the sizable reduction in forb cover on the control plots

TABLE 4.—PERCENTAGE COMPOSITION OF GROUND COVER ON SPRAY AND CONTROL PLOTS IN 1956 AND 1957

Ground Cover	SPRAY PLOTS		CONTROL PLOTS	
	1956	1957	1956	1957
Bare ground	49	59	49	57
Litter	3	12	3	7
Rock	2	3	4	5
Grasses	14	18	9	10
Forbs	32	8	35	21

TABLE 5.—STOMACH CONTENTS OF POCKET GOPHERS COLLECTED FROM GRAND MESA

Collection Location	Number of Stomachs	Date Collected	FOOD ITEMS (PER CENT BY VOLUME)			
			Forbs	Grasses	Stems & Leaves	Roots
UNTREATED AREAS						
Spray plots prior to spraying	37	July 1956	82	18	60	40
Control plots	42	July–Aug. 1957	89	11	67	33
Control area near plots C-1 & C-2	13	Oct. 1957	64	36	50	50
TREATED AREAS						
Plots sprayed in 1956	14	Aug. 1957	49	51	67	33
Area sprayed in 1957	13	Oct. 1957	26	74	65	35
Area sprayed in 1956 and resprayed in 1957	11	Oct. 1957	9	91	67	33

is not readily apparent. While litter increased somewhat more on the sprayed plots, possibly because of dead forbs or the presence of litter under formerly live plants, the amount of bare soil exposed was not affected by treatment.

FOOD HABITS OF POCKET GOPHERS

Food habits were determined by analyzing stomach contents of gophers trapped during the course of the study. The collection contained 37 animals taken from spray plots before treatment in 1956; 14 from these same plots following treatment in 1957; and 42 captured on control plots in July and August 1957. Additional gophers were trapped in October 1957 from the control area and at two other locations. One of these had been sprayed in 1957 and the other was sprayed both in 1956 and 1957. On the area sprayed for the first time in 1957, most of the forbs (at least the parts showing aboveground) appeared to be dead. On the area that was sprayed twice, very few living forbs remained.

Pocket gopher stomachs were frozen until examined in the laboratory. Freezing kept the contents in a more natural state and thus facilitated identification of food particles.

A technique similar to that developed by Dusi (1949) was used in analyzing stomach contents. Slides and microphotographs showing tissues of plants common on Grand Mesa were used in identification of plant materials. Samples of individual plant species that had been fed to caged gophers were also recovered and used for reference.

Examination was made in the following manner: Stomachs were thawed, opened, and the contents cleaned by washing. Contents then were screened, and representative samples were placed on microscope slides for identification of various plants. Ten random spots were studied at 100 magnification, and the percentage volume of roots and stems (and leaves) of forbs and grasses was estimated and tabulated. The remaining contents were dried and saved for later re-examination.

Stomach contents were examined twice. In the second analysis Hertwig's solution was used to clear the dried plant material as suggested by Baumgartner and Martin (1939).

Stomach analyses revealed drastic changes in the food habits of pocket gophers as a result of spraying (Table 5). Whereas 82 per cent of their diet consisted of forbs before spraying in 1956, they ate nearly equal amounts of grass and forbs on the same areas 1 year later. On control plots in 1957, their diet was essentially the same as that on sprayed plots in 1956 before treatment. On areas that were sprayed both in 1956 and 1957, and where few living forbs remained, their diet was only 9 per cent forbs and 91 per cent grass in October 1957.

The rapidity with which gopher food habits changed is indicated by the diet of animals captured in October from the area sprayed in July 1957. These gophers were eating 26 per cent forbs and 74 per cent grass, compared with 64 per cent forbs and 36 per cent grass on a nearby control area.

The proportion of plant material taken by gophers from above and below ground was not affected by spraying. As shown in Table 5, the ratio was fairly consistent regardless of treatment. Stems and leaves provided about two-thirds of the diet on all sites except the control area from which gophers were trapped in October 1957. At that location, gophers ate equal amounts of roots and aboveground parts of plants.

The amount of aboveground plant material (stems and leaves) consumed by gophers was higher than reported by former workers (Cummings, 1946; Tryon, *op. cit.*; Aldous, 1951). Aboveground feeding was further indicated by recovery of aluminum tracer in the stomachs of pocket gophers that had eaten aluminum-treated grain scattered on the surface of the ground near gopher diggings.

The main food items in pocket gophers' stomachs, listed in order of frequency of identification, were as follows:

Untreated area—(spray plots before treatment in 1956 and control plots in 1957)

Forbs: Dandelion and agoseris, western yarrow, Rydberg penstemon, peavine (*Lathyrus* spp.), lupine (*Lupinus* spp.), avens (*Geum triflorum*), eriogonum (*Eriogonum* spp.), knotweed (*Polygonum* spp.).

Grasses: Needlegrass (*Stipa* spp.), slender wheatgrass, spike trisetum (*Trisetum spicatum*), prairie Junegrass (*Koeleria cristata*), sedges, brome (*Bromus* spp.).

Area sprayed in July 1956 (gophers trapped August 1957)

Forbs: Dandelion and agoseris, western yarrow, Rydberg penstemon, knotweed.

Grasses: Needlegrass, slender wheatgrass, sedges, prairie Junegrass, spike trisetum, brome.

Area sprayed in July 1957 (gophers trapped October 1957)

Forbs: Dandelion and agoseris, western yarrow.

Grasses: Needlegrass, prairie Junegrass, slender wheatgrass, spike trisetum, brome, alpine timothy (*Phleum alpinum*), bluegrass.

Area sprayed in July 1956 and July 1957 (gophers trapped October 1957)

Forbs: Dandelion and agoseris, western yarrow, Rydberg penstemon.

Grasses: Needlegrass, slender wheatgrass, spike trisetum, alpine timothy, prairie Junegrass, bluegrass.

The above list relates only to the frequency of occurrence of plant material in the stomachs and not to the relative amounts of each material eaten. Dandelion and agoseris are listed together because their roots are very similar and difficult to distinguish. Dandelion and agoseris, western yarrow, and Rydberg penstemon were the most common forbs in the stomachs, and needlegrass and slender wheatgrass were the most common grasses. Unidentified food particles comprised only a small portion of the stomach contents.

DISCUSSION

The reasons for the decline in pocket gopher numbers on herbicide-treated areas are not known. Movement of gophers to untreated areas seems unlikely because of the large acreages involved. Therefore, reductions were probably due either to mortality, a decrease in breeding, or to both of these factors. These may have been caused by depletion of essential food supplies or by direct or indirect toxicity of the herbicide.

Most of the plants that pocket gophers seem to prefer were drastically reduced by the spray treatment. Production of dandelion was reduced 91 per cent; agoseris, 99 per cent; western yarrow, 85 per cent; and Rydberg penstemon, 88 per cent. It is possible, therefore, that reduction in these and other food items may have been responsible for the sharp decline in gopher populations on areas treated with 2,4-D.

Food-habits data show that the diet of pocket gophers was about 85 per cent forbs before spraying where the herbage production consisted of 75 per cent forbs and 25 per cent grass. On the spray plots, where the relative production of grass increased to 70 per cent and forbs decreased to 30 per cent, gophers ate equal amounts of each. This may indicate that they were seeking

the relatively few forbs that remained on the area after spraying. Pocket gopher stomachs collected from the area sprayed 2 years in succession contained 91 per cent grass, probably because grass was about the only food available. Whether or not gophers can subsist on a diet of grass alone is not known.

To determine whether 2,4–D might have a direct toxic effect, Halvorson (1956) offered oat groats treated with a solution of 0.5 per cent active 2,4–D to five caged gophers for 5 days. These animals showed no signs of being affected by the 2,4–D in their diet. Although 4 of the 5 preferred untreated food, 2 of them consumed more than 4 gm. of the treated oat groats each day. This represents about 200 mg. of 2,4–D for each kg. of body weight each day for 5 days. Oral dosages resulting in 50 per cent mortality in other mammals are: mice, 376 mg./kg.; rats, 666 mg./kg.; rabbits, 800 mg./kg.; and dogs, 100 mg./kg. (Rudd and Genelly, 1956).

Indirect effects of 2,4–D on animals are less well known. Some studies have shown that rabbits, chickens, and livestock are not affected by eating forage sprayed with 2,4–D (Rudd and Genelly, *ibid.*; Mitchell, Hodgson, and Gaetjens, 1946; Grigsby and Farwell, 1950). On the other hand, Stahler and Whitehead (1950) cite instances where cattle became ill and died after eating certain weeds treated with 2,4–D. They found that beet leaves treated with 2,4–D contained toxic quantities of potassium nitrate and concluded that grazing or feeding of sugar beet tops, oats, hay, and pigweed and other closely related weeds should be undertaken with caution following treatment with 2,4–D. A similar study by Berg and McElroy (1953) showed that spraying at a rate of 2 to 8 equivalent oz. of 2,4–D per acre resulted in a moderate increase in the nitrate content of several weeds. Fertig (1952) found that the peak accumulation of nitrate appears to fall on the second or third day after treatment and recommended caution in spraying where livestock were grazing. While nitrate poisoning might be the answer, it is not possible, on the basis of present knowledge, to conclude that pocket gophers were poisoned by this agent.

SUMMARY

Aerial spraying of weedy, mountain rangeland in western Colorado with 2,4–D resulted in the following changes 1 year after treatment:

1) Pocket gopher populations were reduced 87 per cent.
2) Production of perennial forbs was reduced 83 per cent and grass production increased 37 per cent.
3) The diet of pocket gophers changed from 82 per cent forbs to 50 per cent forbs, and from 18 per cent grass to 50 per cent grass.

Untreated control areas showed no significant change in gopher numbers or herbage production from one year to the next. Gopher food habits did not change on untreated areas. About two-thirds of the gophers' diet during summer months consisted of aboveground plant material. The most common food items identified in pocket gopher stomachs were dandelion, western yarrow, and Rydberg penstemon. Although the reasons for the decline in gopher numbers on sprayed areas are not known, depletion of essential food items and nitrate poisoning are the most likely explanations.

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OBSERVATIONS ON *LEUCOCYTOZOON* IN PEN-RAISED AND FREE-RANGING WILD TURKEYS[1]

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This paper is a preliminary report on the occurrence of a *Leucocytozoon* in pen-raised and free-ranging wild turkeys (*Meleagris gallopavo*). The field aspects of this investigation were conducted on the 12,000-acre Cumberland State Forest in the Piedmont region of Virginia. This area was utilized as a study area because (1) it is managed and controlled by the Virginia Commission of Game and Inland Fisheries and the Virginia Forest Service, (2) it supports a resident population of native wild turkeys, in which infections due to *Leucocytozoon* have been found, (3) the area has been the approximate geographical center of Virginia's better turkey range, (4) the forest encloses the State Game Farm and propagation pens in which *Leucocytozoon* frequently infects many pen-raised wild turkeys, and (5) the area is traversed by a number of streams that are breeding areas for simuliid vectors.

The primary objectives of this study on free-ranging and pen-raised wild turkeys were: (1) to determine the period during which infections were transmitted, (2) to identify the vector or vectors, and (3) to determine whether the organism was patho-

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genic to young domestic and pen-raised wild turkey poults and to pen-raised wild turkeys 10 months of age.

Mosby and Handley (1943) first reported the occurrence of *Leucocytozoon* in free-ranging wild turkeys in Virginia. Their data also indicated the occurrence of the organism in pen-raised wild turkeys on the wildlife refuge at Camp Lee, Virginia. They were unable to distinguish the gametocytes of the organism from those of *L. smithi* Laveran and Lucet in domestic turkeys.

McDowell (1954) reported the occurrence of *Leucocytozoon* in several wild turkeys on the Cumberland State Forest, although he did not assign the organism to any species. Reports received by McDowell (*ibid.*) of sick and lethargic birds on the forest, coupled with an occurrence of *Leucocytozoon* in all of nine adult wild turkeys examined at checking stations on the Cumberland forest at the beginning of the present study, suggested this organism as a possible cause of mortality.

Disease due to *Leucocytozoon* has been considered previously by several workers as a possible cause of population losses in wild game birds. Clarke (1938) indicated that *L. bonasae* Clarke was possibly responsible for mortality in grouse chicks. Erickson, *et al.* (1949) and Erickson (1953), studying infections of *L. bonasae* in the ruffed grouse (*Bonasa umbellus*) for a period of 11 years in Minnesota, concluded that it probably was a harmless parasite and had little influence on the grouse cycle. He suggested the possibility that the disease might cause juvenile mortality.

Borg (1953) in Sweden has investigated disease due to *Leucocytozoon* in capercaillie (*Tetrao urogallus*), black grouse (*Lyrurus tetrix*), and hazel grouse (*Tetrastes bonasia*) and presents an excellent summary of literature regarding pathogenicity of various species of *Leucocytozoon*. With the exception of *L. simondi* Mathis and Leger, he did not consider species of the genus to be serious pathogens except under special circumstances.

Laveran and Lucet (1905) described a blood protozoan from domestic turkeys in France and named the organism *Leucocytozoon smithi*. Johnson, *et al.* (1938) studied a blood protozoan in domestic turkeys in Virginia and considered the organism to be *L. smithi* L. and L. Hinshaw and McNeil (1943), Banks (1943), Savage and Isa (1945), Stephan (1922), Travis, *et al.* (1939), and West and Starr (1940) have all described disease outbreaks in domestic turkeys which were attributed to *smithi* infections.

Comparisons of gametocytes from old infected birds examined during the present study were made with the published description (Laveran and Lucet, *op. cit.*) of *L. smithi*. Species identification of leucocytozoons based on gametocyte morphology alone is a very unsatisfactory procedure. In view of its common occurrence in turkeys and its similarity to the gametocytes of the organism described by Laveran and Lucet (*ibid.*), the organism encountered in this study is tentatively designated as *L. smithi*.

L. smithi in turkeys has been incompletely investigated from many aspects. Skidmore (1932) described a number of deaths in turkeys in Nebraska and identified the causative agent as *L. smithi*. Black flies identified as *Simulium occidentale* Townsend were observed to feed on these turkeys, and experimental proof of the transmission of the protozoan is reported, although no sexual stages in the fly are described.

Johnson, *et al.* (*op. cit.*) appear to be the first to have attempted an elucidation of the life history of *L. smithi*. They found that *Simulium nigroparvum* Twinn (= *jenningsi* Malloch) was capable of transmitting the disease to domestic turkeys and that gametocytes remained in the blood of the turkey for as long as 6 months. They based their work largely on the similarity of stages of their organism to stages in the life cycle of *L. anatis* Wickware (= *simondi* Mathis and Leger), as determined by O'Roke (1934). Trophozoites, schizonts, or merozoites were never found with any certainty in their material: Gamete formation from gametocytes was noted in the stomach contents of the fly. Zygotes and ookinetes were observed, but no oocysts

could be found. There was, therefore, a gap from ookinete to sporozoite that was not made clear. They reported "numerous deaths" in domestic turkeys in Virginia between 1933 and 1935, with "sporadic cases" in the years 1936–37. The deaths occurred mainly in the months of July and August. In 1933, about 30 per cent of the infected turkeys died in one area. Bacteriological studies of these birds gave negative results, although *Leucocytozoon* was present. These authors indicated that young turkeys up to 12 weeks of age were chiefly affected.

The first description of schizont development in natural *smithi* infections of domestic turkeys was made by Newberne (1955). Richey and Ware (1955) also described a schizont from an artificially induced infection of *smithi*.

METHODS AND MATERIALS

Experimental birds consisted of 4 unsexed Golden Bronze poults (6 weeks of age), 160 White Holland poults (3–8 weeks of age), and 80 pen-raised wild turkeys (4 weeks and 10 months of age). The pen-raised wild turkeys were the progeny of wild gobblers and hens reared from a wild strain through approximately 16 generations at the Cumberland Game Farm.

Pen-raised wild turkeys from fly-proof areas were unobtainable for experimental use. However, slides were made of blood from several hundred unsexed turkeys (10–22 months of age) by McDowell (*op. cit.*) and the author; these birds had spent their entire life at the game farm. To the writer's knowledge, there was never any indication of infection in these birds and, in addition, negative blood smears were obtained from all birds; hence, it was felt that they might be considered to be parasite-free. McDowell (*ibid.*) also indicated that no bird examined at the game farm was positive for *Leucocytozoon* if the bird had spent its entire life at the farm.

Other birds used were six White Pekin ducklings (6 weeks of age), and six Rhode Island Red chickens (8 weeks of age). Birds were obtained unsexed from a commercial hatchery where there had been little chance of their being exposed to the bite of black flies, the potential vectors of the disease. In addition to these experimental birds, 18 free-ranging wild turkeys were examined for infections by blood smears at game-checking stations on the area.

Unsexed older turkeys (8 weeks and 10 months of age), both pen-raised wild and domestic, were exposed to infections in a 100-ft. by 50-ft., wire-enclosed, open-top pen in the woods (hereafter referred to as Pen 1). These birds were forcibly confined at night in a 10-ft. by 10-ft. by 6-ft. coop at one end of the exposure pen. Young turkeys (3 weeks of age) were exposed in 60-ft. by 8-ft. by 5-ft. wire enclosed runs to which an accessible brooder house was attached (Pens 2 and 3). Birds were forcibly confined in the brooder house at night and during cool and inclement weather. The brooder house was maintained at 90°–95°F. by means of a kerosene stove. Runs were constructed of 1-in. by 2-in. mesh sides and had a wooden floor covered with litter. Poults were retained in the runs by two 12-in. boards placed one on top of the other along the sides and end of the run.

Birds spoken of as "breeders" in this paper are pen-raised wild hen turkeys that have been placed in open, ground-bottom breeding pens in the woods to be mated with native wild gobblers. Breeders are young hens hatched the previous summer, hence approximately 10 months of age. Hens normally are utilized as breeders for only one breeding season. These birds remain in the open pens from approximately early March through mid-July.

When removed from the breeding pens, breeders are retained, for later Virginia releases, in 60-ft. by 8-ft. by 5-ft. wire runs at the game farm. All the progeny resulting from the spring breeding program are raised in similar runs. The game farm is located in an open field with a woods border lying approximately 50 ft. from the nearest run.

To facilitate record keeping, birds first were marked by numbered metal tags and later by numbered adhesive bands. Adhesive bands were replaced each week or each second week as they became worn.

Black flies were collected from exposure pens and sustained insofar as possible on sucrose solution. In an attempt to induce artificial infections, groups of flies were macerated in physiological saline solution and injected into uninfected birds and into birds assumed to be uninfected. Subsequent to injection, birds were retained in fly-proof cages.

Determination of positive infections and height of parasitemia was made by examination of blood smears from wing veins. Smears were fixed in methyl alcohol and stained with a 1:20 dilution of Giemsa stain for 45 minutes each. Birds were considered infected when examination of blood smears for a maximum of 30 minutes revealed parasites.

NATURAL INFECTIONS

Study of blood smears of free-ranging wild turkeys from the Cumberland State Forest and pen-raised birds held regularly at the game farm indicated a rather definite pattern of infection. In 1953, two free-ranging wild hens killed in the Cumberland forest on February 26, and March 20, respectively, were positive for *Leucocytozoon smithi*. Two wild gobblers shot on April 7, 1953, on the Buckingham State Forest, located 25 miles away, were positive (McDowell, *op. cit.*). Subsequent examination of nine adult free-ranging wild birds at game-checking stations on the Cumberland forest during the hunting seasons of 1955–56 and 1956–57 revealed that all were infected with *L. smithi*. Nine juvenile birds killed on the Cumberland forest during these same seasons were all negative. Juvenile birds may be defined as those birds hatched the preceding May and June, thus being less than 1 year of age at the fall hunting season following the time of hatching.

On September 19, 1952, a single blood smear was taken from each of a sample of 21 old breeders at the game farm. Eighteen of the birds were positive, and three were doubtful infections. Fourteen young birds (1952 hatch and approximately 4 months of age), held approximately ½ mile from these infected breeders, were all negative when examined by means of blood smears. The entire group of 239 breeders from which the sample of 21 was selected on September 19, 1952, was examined by McDowell (*ibid.*) by blood smear on February 20, 1953. This examination revealed 237 positive and 2 doubtful infections. One hundred additional young of the previously sampled 1952 hatch, including some held in pens immediately adjacent to infected breeders, were tested on February 26, 1953. All of these slides were negative for *Leucocytozoon* (McDowell, *ibid.*). Although McDowell did not assign the organism he studied to any species, it is the opinion of the writer, based on examination of some of McDowell's slides, that he was dealing with the organism which I have designated in this paper as *L. smithi*.

From the young birds (1952 hatch) sampled on September 19, 1952, and February 26, 1953, birds were selected for breeders and placed in the open propagation pens in the woods in early March 1953. Three of these birds from each of 15 propagation pens were examined when returned to the game farm in late June, and all were found to be positive for *Leucocytozoon* (McDowell, *ibid.*).

In 1957, 110 breeders from seven different propagation pens were examined when returned to the game farm in July. Although a sample of 25 of these breeders failed to reveal a positive infection prior to exposure in the propagation pens, all 110 birds were positive when brought from the pens in July. The entire group of breeders had been selected from young hatched in May, June, and July of 1956, and held at the game farm since that time.

On the basis of these observations, it would appear that a general pattern of infection existed on the area. Breeders apparently became infected when placed in the open propagation pens in the woods. Free-ranging wild turkeys that were examined were infected only if they were more than 1 year old. Transmission of the disease apparently was not taking place between infected breeders and young birds of the year at the game farm.

In view of the high rate of infection of breeders when placed in the propagation pens, it appeared that a ready reservoir of infection in carrier birds existed on the forest. O'Roke (*op. cit.*) indicated that wild ducks might serve as a reservoir of infection of *L. anatis*. Johnson, *et al.* (*op. cit.*) have indicated that wild turkeys might serve as a similar reservoir for *L. smithi*. In view of the occurrence of *Leucocytozoon* in the wild turkeys older than one year on the Cumberland forest, I believe that the carrier birds on this area were the native free-ranging wild turkeys. The following experiments were carried out in an effort to determine the time when the disease was transmitted.

Experiment I.—Twenty unsexed, pen-raised wild turkeys (10 months of age) were exposed in Pen 1 on March 5, 1955. These birds were negative on March 12, 19, and 26, and on April 2. All birds were positive on April 9.

Experiment II.—In 1956, 12 unsexed, pen-raised wild turkeys (10 months of age) were exposed in Pen 1 on February 25. These birds were negative on March 3, 10, 17, and 24. On March 31, two birds were positive, and on April 7 all except three birds were positive. On April 14, all of the birds were infected.

In the case of the above two experimental groups, no attempt was made to introduce a new series of birds each week subsequent to the time of infection, although it was apparently desirable.

In 1953 and 1954, a group of young wild turkey poults (between 1 and 3 weeks of age) was exposed in Pens 3 and 4, respectively, by McDowell (*op. cit.*) and the writer. Young pen-raised wild turkeys could not be used in any case prior to mid- or late May, the approximate date of the first hatching. McDowell (*ibid.*) exposed a group of these young in the woods in Pen 4 in June 1953 with known-infected hens. These young birds were negative at the time of exposure. Young birds and adults were tested weekly from June 30 to August 26, 1953. Although the infected hens remained positive throughout this period, none of the young birds tested positive during the period of examination.

Experiment III.—In 1954, a second group of 20 young was exposed by the writer, the method of exposure varying somewhat from that previously used by McDowell (*ibid.*). Exposure was made in a small wire run (Pen 3) of ½-in. poultry mesh. This run was attached to a brooder house heated by a kerosene stove. Young birds were allowed to spend the daytime in the open run but were forcibly enclosed in the brooder house at night and about 10 per cent of the daytime when the weather was inclement. This exposure unit was placed inside exposure Pen 1 used in some preceding experiments. In addition, 20 infected breeders were placed within Pen 1. Young birds and infected breeders were tested at the time of exposure and weekly from May 28 to July 16. Although breeders remained positive throughout this period, none of the young birds tested positive.

It may be seen that in both 1955 and 1956, experimental groups I and II first showed positive blood smears regularly between April 1 and April 15. On the basis of the apparent failure of young to become infected subsequent to May 28, the possibility exists that the infective period terminates prior to that time unless the results are due to marked annual variations in the infective period.

Experiment IV.—Experiments were also carried out to determine the time at which transmission of the disease ceases. On March 16, 1957, 10 White Holland poults were exposed in a 60-ft. by 8-ft. by 5-ft. run (Pen 2) attached to a brooder house similar to the one used in Experiment III. This exposure unit was immediately adjacent to Pen 1 used in Experiments I and II. Inasmuch as pen-raised wild turkey poults were unavailable this early in the season, domestic turkey poults were used. Although the *Leucocytozoon* encountered in this study tentatively has been assigned to *L. smithi*, its infectivity for domestic turkeys was unknown. Therefore, a control group of eight uninfected pen-raised wild birds (1955 hatch) was placed in Pen 1 adjacent to the

run in which the young domesticated birds were exposed.

Ten additional White Holland poults were exposed in the run on March 23 and a new group of 10 each week thereafter until April 13. All birds exposed were from one hatch, hence, each week the age of the new exposure group at the time of exposure increased by 7 days. Each group was placed in the run with the previously exposed groups.

All birds were tested prior to exposure and found to be negative for *L. smithi*. Birds were tested once a week subsequent to the time of exposure. The eight pen-raised wild turkey controls were all positive on or by April 13. On April 15, none of the experimental birds in the run had become infected. By this date, the weather became warm enough so that the 8-week-old birds could be exposed safely in the open pen (Pen 1) without brooding.

Ten new 8-week-old birds were exposed in the open pen (Pen 1) on April 20 and a control group of 10 birds placed in the wire run (Pen 2). All birds tested negative for *L. smithi* at the time of exposure. A new group of 10 birds was exposed in the open pen on May 4, 11, 18, and 25. Five additional controls were placed in the run on each of these dates. All 10 birds exposed on April 20 were positive on May 11, although the 10 control birds exposed on that date never became infected. Three of the 10 birds exposed on May 4 were positive on May 18, although the other seven birds did not become infected. Although all birds were tested weekly until July 5, no birds exposed May 11 or later became infected during the study period.

The combined data on infected birds for all years of the study indicate a rather sharp period of infectivity beginning approximately April 1 and ending May 15. As the infective period might be correlated with the activity pattern of one or more species of simuliid vectors, a study of these vectors was made.

TABLE 1.—SEASONAL DISTRIBUTION BY SPECIES OF COMBINED BLACK FLY COLLECTIONS IN 1955, 1956, AND 1957, CUMBERLAND STATE FOREST

Date	Specimens Collected			
	Prosimulium hirtipes	*P. magnum*	*Simulium nigroparvum*	*S. venustum*
Mar. 1–12	101	0	0	0
13–26	260	5	0	0
27–31	443	14	0	0
Apr. 1–9	520	3	0	0
10–23	684	1	0	3
24–30	360	0	15	0
May 1–7	200	0	21	16
8–14	30	0	76	21
15–31	15	0	810	99
June 1–15	1	0	1,341	156
16–30	0	0	710	10
July 1–16	0	0	912	114
17–31	0	0	634	336
Aug. 1–15	0	0	405	3
16–31	0	0	350	41

VECTOR COLLECTIONS

Collections were made during the spring and summer seasons of 1955, 1956, and 1957 in the Cumberland State Forest and identified by the writer. Flies were collected from breeding pens, along streams, and in other widely dispersed portions of the forest. Some few specimens were collected following their engorgement on turkeys. Most of the streams in the forest are rather sluggish and slow moving, hence are not especially suitable black fly breeding areas. It is my opinion that black fly populations here do not reach the density found in the forests of the more northern states or as observed in some of the western sections of Virginia. No effort was made to collect in a quantitative manner. I feel that the relative abundance of the species present at the time of collection is indicated roughly by the sample collected. Since the annual distribution pattern of fly species was similar each year, the collections are summarized for 1955, 1956, and 1957 in Table 1.

Underhill (1940) has indicated that both *Simulium nigroparvum* Twinn and *Simulium slossonae* Dyar and Shannon feed on domestic turkeys in Virginia. He reported *S. nigroparvum* as common in the mountains and Piedmont but relatively scarce in the Coastal Plain. *S. slossonae* was collected by him only in New Kent, a Coastal Plain county. Although Underhill reported no

collections from Cumberland County, he indicated that *S. nigroparvum* was taken as far east as Richmond, Virginia.

Only four species of black fly were collected on the Cumberland forest and the incidence in the sample indicates the following seasonal distribution. The first black fly adults to emerge in the spring are *Prosimulium hirtipes* Fries. This species is present until the first of May, at which time it becomes scarce or absent. *P. magnum* Dyar and Shannon emerges at about the same time as *hirtipes* but never appears to be abundant. *Simulium nigroparvum* and *S. venustum* Say are common from the middle of May until the end of August.

Data in this study indicate that gametocytes of *L. smithi* first appear in the blood of infected turkeys on the Cumberland forest during the first two weeks of April. Apparently, transmission does not take place subsequent to May 10. If the developmental period of *L. smithi* is similar to that of *L. simondi,* as determined by Fallis, *et al.* (1951), it would appear that the infections were transmitted by flies that had fed on infected birds a minimum of 10–12 days prior to the time at which infections were first seen in turkeys. The vector would seem to be a species of fly emerging around the middle of March. Fly collections indicated *P. hirtipes* as the most likely vector on the area.

Artificial Infections

Fallis, *et al.* (1956) have reported the collection of black flies from the walls of cages covered with nylon mesh following the exposure of ducks to these flies outside the cages. Engorged flies crawled on the mesh from the ducks once the birds were introduced into the cage. Underhill (*op. cit.*) reported the collection of large numbers of *S. nigroparvum* following their engorgement on domestic turkey blood. Although swarms of *nigroparvum* were often seen around experimental turkeys on the Cumberland area, none was ever observed actually engorging itself with blood.

Fallis, *et al.* (1956) reported that they were able to keep flies in glass tubes, feeding them upon sucrose. Artificial infections of *L. simondi* in ducks were established by the injection of flies macerated in Tyrode's solution after the flies had fed upon infected ducks. Johnson, *et al.* (*op. cit.*) also reported that artificial infections of *L. smithi* were induced in domestic turkeys by the injection, following engorgement, of macerated flies in saline solution. Richey and Ware (*op. cit.*) induced infections of *L. smithi* in uninfected domestic turkeys by injection of several *Simulium slossonae* a few days after their engorgement on infected birds.

Although swarms of both *P. hirtipes* and *S. nigroparvum* were seen around experimental turkeys during the present study, it was difficult to obtain flies that had engorged on turkeys. A number of *P. hirtipes* that had engorged on infected turkeys were collected, but could not be maintained alive on sucrose beyond 1½ days. On April 7, 1956, 20 *hirtipes* were collected from Pen 1 in which positive turkey breeders were confined. None of these flies was engorged with blood at the time of collection. Flies were macerated in saline solution and 1 cc. of inoculum injected intramuscularly into each of four 10-month-old, negative, pen-raised wild turkeys. On the fourteenth day following injection, all four birds had positive blood smears and a relatively high parasitemia.

The injection experiment was repeated 14 days later. Saline suspension of 40 macerated *hirtipes* was used and experimental birds were four Golden Bronze poults. All four birds developed a high parasitemia by the fifteenth day and three of the four birds died on the seventeenth day. At the same time, a part of the same inoculum was used to inject six White Pekin ducklings and six Rhode Island Red chicks. Infections did not develop in these two species.

On April 20, 1957, similar injections of macerated *hirtipes* in saline suspension were made into five, 8-week-old, negative White Holland poults. All birds had positive blood smears 16 days later. The parasitemia was rather low in all five birds used in this experiment.

In June and July 1957, five different attempts were made to induce artificial infections in White Holland poults by injections of *S. nigroparvum*. The procedure used was the same as that mentioned above. No bird became infected subsequent to these injections. When injecting flies not observed to have fed on infected turkeys, it was less likely that flies were in an infective stage. Although sexual stages of parasites were not observed in stomach smears from *hirtipes* or *nigroparvum*, development to the infective sporozoite stage in *hirtipes* was indicated by these experiments. Development in *hirtipes* to the ookinete stage was reported by Fallis, *et al.* (1951).

PATHOGENICITY AND PARASITEMIA

Pathogenicity and symptoms of *L. smithi* in domestic turkeys were indicated by Johnson, *et al.* (*op. cit.*). Typical visible symptoms lasted only 2 or 3 days, at which stage the birds either died or recovered. Sick birds lost their appetite, appeared droopy, and had a decided tendency to lie down. No gross lesions were noted with the exception of inflammation of the duodenum. Skidmore (*op. cit.*) reported that sick birds exhibited general body weakness, occasional cyanosis of the head, emaciation, and anaemia. The liver and spleen were somewhat congested, the spleen showing a slight amount of enlargement.

Since all wild turkey breeders at the State Game Farm became infected in the propagation pens, any adverse effects on the birds might be of considerable importance to the breeding program.

Complete quantitative data on parasitemias will be reported upon in another paper. The number of gametocytes in the blood of native wild turkeys during the hunting season has, in every case inspected by the writer, been extremely low. These are carrier birds that apparently have recovered from any detrimental effects of the disease. On the other hand, experimental turkeys have been observed for symptoms and deaths throughout the course of their infections. Johnson, *et al.* (*op. cit.*) mentioned "large numbers" of gametocytes in domestic turkeys, but the photographs published by these authors did not support this statement. Banks (*op. cit.*) described subcutaneous hemorrhages and mild hemorrhagic enteritis of the duodenum in infected domestic turkeys. Savage and Isa (*op. cit.*), also working with domestic turkeys, stated that infections were characterized by depression, loss of strength, and diarrhea. West and Starr (*op. cit.*), reported three types of infection: (1) the peracute form in which apparently healthy birds died suddenly following a few convulsive seizures, (2) the less acute form with weakness and progressive emaciation and, (3) the chronic form, characterized by arthritis, distortion of the hock joint, and lameness.

In this study, external manifestations of the disease in infected wild turkey breeders and experimental birds have been very few. Most birds with the disease appeared to be perfectly normal externally. Parasitemias were low at their peak, despite the fact that birds were exposed to possible reinfection over a period of weeks.

The level of parasitemia was determined by examining thin blood smears for 5 minutes with the 10× ocular and 4-mm. objective of the microscope. Five-minute counts were made in order to get figures more comparable to those of Chernin (1952), who cites the errors inherent in this method of quantification. The highest level of parasitemia observed in any breeder was 90 gametocytes per 5-minute count. The lowest infections detected were three gametocytes per 30-minute count. Since breeders were studied only when removed from the propagation pens in late June or early July, they may have passed their peak parasitemia.

Experimental turkeys, however, were examined either daily or weekly. The highest parasitemia recorded from these birds was 101 gametocytes per 5-minute count. There was a gradual decline in the number of gametocytes once the peak was reached. A few gametocytes were found consistently in blood smears of those birds studied throughout the winter.

Only three experimental wild turkeys died during the study. Death was attributed to

secondary infections of blackhead in two cases. In the third case, and in several cases of infected birds sacrificed, no pathology was observed other than slight hemorrhaging of the intestinal mucosa. Some of the breeders and some of the experimental wild birds became somewhat droopy during their infection, but droopiness did not appear to be a consistent manifestation of the disease.

Two outbreaks of *Leucocytozoon* occurred in a domestic flock of White Holland breeders in an adjoining county in 1956. These birds were on free range and had access to the open woods. According to the owner, no mortality resulted, but there was a noticeable decline in productivity of eggs.

Natural infections in the White Holland poults were more severe and symptoms of the disease more noticeable than in the pen-raised wild birds. Maximum parasitemia observed was 180 gametocytes per 5-minute count. Birds with infections at this level characteristically became very emaciated. Many of them appeared to be lame or exhibited great difficulty in standing. Infected birds sat quietly and did not move willingly except when prodded. When caught for examination, excited birds sometimes collapsed on the ground. Once a bird collapsed in this manner, it rarely was able to regain its feet. Following collapse, birds did not eat, became emaciated, and ultimately died.

At autopsy, birds with the highest level of parasitemia exhibited hemorrhaging in the intestinal mucosa and some hypertrophy of the liver and spleen. Birds that recovered from the highest parasitemia became carriers, but never gained as much weight as their uninfected exposure mates. Of the 21 White Holland turkeys that became infected, seven died following excitement and collapse. Pathological conditions indicative of infections due to organisms other than *Leucocytozoon* were not evident. The remaining 14 birds were retained for relapse studies.

GAMETOCYTE MORPHOLOGY

Examination of slides from birds with infections contracted from field exposures and from injections indicated a similarity of gametocyte morphology in both types of infections.

Borg (*op. cit.*) reported morphological variations in several species of *Leucocytozoon* described as spindle forms and round forms, and summarized the literature on this subject. In the present study, very young gametocyte stages were not observed. Both the typical spindle forms and the round forms occurred. Spindle forms constituted an estimated 95 per cent of the gametocytes observed. Several younger forms intermediate in appearance between round and spindle forms occasionally occurred. The youngest forms seen were stages in which the gametocyte was round and the host cell nucleus was undistorted but displaced to one side. Ring stages, as described by Cook (1954) for *simondi* infections, could not be found. A. M. Fallis (*in litt.*, 1957) states that he has experienced no difficulty in finding young developmental forms of gametocytes in *simondi* infections but that they often may be overlooked in very light infections.

Older gametocytes observed in *smithi* infections normally split the nucleus of the host cell, with one-half of the nucleus being displaced to each side of that cell. In those younger stages observed, infected host cells invariably appeared to be erythrocytes. Cook (*op. cit.*), using a haemoglobin specific stain, has shown that erythrocytes also are the cells infected in *simondi* infections of ducks.

When stained with Giemsa, distinct differences exist between macro- and microgametocytes of *smithi*. The cytoplasm of a macrogametocyte is highly vacuolate and stains a very deep blue. The nucleus stains red, and is rather variable in its location. The cytoplasm and nucleus of the microgametocyte stain much less intensely than do those of the macrogametocyte.

HOST SPECIFICITY

Limited injection experiments using chickens and ducks indicated that these birds were not susceptible to the disease. The rapidity of transmission of the disease to breeders and experimental birds during the

early spring implied a reservoir of infection, in addition to the indigenous free-ranging wild turkey population.

Blood smears were made during all seasons in 1955 and 1956 from a number of species of birds on the forest. Examination revealed that *Leucocytozoon* was common in crows (*Corvus brachyrhynchos*), grackles (*Quiscalus quiscula*), and robins (*Turdus migratorius*). In these three species, only round gametocytes were encountered, and gametocytes differed in the three host species only in size. On the basis of gametocyte morphology, the forms seen in crows, grackles, and robins would appear to be one or more species different than *smithi* in domestic turkeys. Since the organism encountered in the present study is considered to be *smithi*, it appears to occur only in domestic and wild turkeys, although further studies may indicate a lack of such host specificity for the species.

DISCUSSION

Disease due to *Leucocytozoon* has been considered in this paper primarily with respect to its relationship to the wild turkey rearing program on the Cumberland State Forest. Transmission of *Leucocytozoon* to breeding hens from the game farm took place rapidly in the spring but only after birds had been placed in open, ground-bottom pens. Transmission to birds held at the game farm in wire runs has not been observed during the course of this study. This may possibly be attributed to the fact that runs at the game farm are located in open fields. Black flies apparently have an aversion to entering these open areas, since none have been observed around these pens.

On the other hand, controlled experiments showed that young birds exposed in the woods in open-top, wire-enclosed pens with wire floors (Pen 2) did not become infected, whereas experimental birds exposed at the same time in large breeding pens with open tops and ground bottoms (Pen 1) became infected. This would indicate that the black fly vector did not enter the wire runs to feed, even though runs were open at the top. Considerable personal observation by the writer has failed to reveal a single instance of a black fly feeding inside a wire-enclosed run, although the same species might be feeding immediately outside.

Injection experiments with *Prosimulium hirtipes* have indicated that it is a vector capable of transmitting the disease to pen-raised wild and domestic turkeys. Similar experiments have failed to indicate *S. nigroparvum* as a vector of the disease to experimental domestic turkeys. The period of infectivity for the disease on the Cumberland forest is such that *P. hirtipes* appears to be the only species responsible for transmission. If so, it is difficult to explain why *S. nigroparvum*, a proven vector in other Virginia counties during June and July of *smithi* to domestic turkeys (Johnson, *et al.*, *op. cit.*), apparently does not naturally transmit infections on the Cumberland forest. Under conditions existing on the area, this fly species may not exhibit ornithophilic tendencies. The parasites encountered in both wild turkeys and experimental domestic turkeys during this study are morphologically indistinguishable from published descriptions of *smithi* and from parasites of domestic turkeys examined in Buckingham County by the writer. It would appear to be implausible to suggest that the organism on the Cumberland forest is a different species than *smithi*, hence not infective for *nigroparvum*. Further studies may clarify the relationships between the potential vectors and the actual transmission of the disease.

Despite the fact that all wild turkey breeders contracted the disease during early spring while in breeding pens, there was little evidence of pathological conditions resulting from the disease. Review of symptoms reported in the literature for *smithi* infections reveals few instances of pathology typically characteristic of heavy blood-protozoan infections. Considerable hypertrophy of the liver and spleen is usually associated with infections of this type and is often quite marked in *simondi* infections in ducks. Some hypertrophy of the liver and spleen of infected birds was encountered

during the present study. Published accounts of *smithi* infections indicate that the height of parasitemia is usually rather low, and such was the case in the birds from the Cumberland forest. Heavy infections, comparable to those reported for *simondi* in ducks, do not seem to occur. If one assumes the organism encountered during this study to be *smithi*, it would be difficult—on the basis of information obtained—to attribute to *smithi* any pathogenicity for pen-raised or free-ranging wild turkeys. Under exposure conditions in which black fly populations are very high, parasitemias might reach a higher level with more serious effects on the infected bird.

Johnson, *et al.* (*op. cit.*) have indicated that infected domestic gobblers do not readily mate and also that productivity of hens may be reduced. Since all breeders at the State Game Farm apparently are infected, an increase in productivity from its present level might well be a factor of considerable importance to the breeding program. When using existing breeding techniques, it would be difficult to design a controlled experiment to measure productivity of infected and uninfected breeders. Such experiments could indicate *Leucocytozoon* to be a problem of more importance than its immediate significance as a direct mortality factor.

The higher level of infection and resulting symptoms, observed in experimental domestic turkeys by the writer and by others, conceivably could be attributed to several factors. The possibility exists that wild turkeys, having long been exposed to infections, have developed some degree of natural resistance to the disease. Conversely, domestic turkeys may be more susceptible to infections. Another consideration is that the domestic turkeys were of a much younger age than the wild birds studied. Most investigators have indicated that young birds were more susceptible to infections than were older ones. The period of infection is such on the Cumberland forest that wild turkeys do not become infected until the birds are at least 10 months old and presumably less susceptible to the disease.

H. Farley (*in litt.*, 1957), on the basis of observations of numerous infected domestic turkeys at the Virginia State Diagnostic Laboratory, has concluded that *smithi* infections are rarely a primary cause of death but that secondary infections by other organisms, in association with *Leucocytozoon*, may cause mortality. It would appear that on the Cumberland forest, *Leucocytozoon* should not be considered as a serious pathogen for either the free-ranging wild or pen-raised wild turkeys. Before *Leucocytozoon* can be completely discounted as a mortality factor, several aspects of its relationship to the wild turkey population should be investigated. The course of infection should be studied in areas in which high populations of black flies occur, in an attempt to determine whether *nigroparvum* and other fly species function as vectors in other parts of the wild turkey range. Should *nigroparvum*, which is active all summer, serve as a vector in other areas, young wild turkeys might then be infected. Finally, the importance of infections due to *Leucocytozoon* in reducing productivity of pen-raised and free-ranging wild turkeys should be considered and evaluated, in order that it might be viewed in proper perspective in the game-management program.

SUMMARY

Infections due to *Leucocytozoon* were transmitted naturally very rapidly to wild turkey breeders from the State Game Farm on the Cumberland State Forest. Transmission of the disease took place only in the woods and not to birds held at the game farm. Infections were transmitted to experimental birds regularly between April 1 and April 15. No birds became infected subsequent to May 15.

Injections of macerated *Prosimulium hirtipes* in saline into uninfected birds produced artificial infections. The period of infectivity may be correlated with the activity of this fly and indicated that it was the only vector transmitting the disease on the area. Infections were not transmitted in the woods by this fly to birds confined

in pens with wire sides and bottom and with open tops. Infections were readily transmitted to birds confined in the woods in large ground-bottom, open-top pens.

Peak parasitemia studied in wild turkeys was 90 gametocytes per 5-minute search. Infections were generally much lower than the peak, and declined gradually once the peak had been reached. Infections reached a much higher peak of 180 gametocytes per 5-minute search in young domestic turkey poults. Few symptoms were observed in wild turkeys that could be attributed to the disease. As it exists in the native wild and pen-raised wild turkeys on the Cumberland forest, *Leucocytozoon* probably should be considered as an innocuous organism. No pathogenicity for wild turkeys could be attributed directly to it. *Leucocytozoon* should be studied in turkeys in other areas in order to determine its possible influence on productivity and on juvenile turkey mortality.

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TURBIDITY AND SEDIMENTATION AT LAKE CHAUTAUQUA, ILLINOIS[1]

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This paper is concerned with sedimentation, and the causes and effects of resuspension of these sediment particles at Lake Chautauqua, a lateral reservoir lake along the Illinois River. Wallen (1951), Irwin and Stevenson (1951), and Buck (1956) have reviewed the pertinent literature relative to turbidity caused by suspended erosion silt as a limiting factor to aquatic life.

During the past 25 years, increased rate of sedimentation resulting from modern agricultural practices has affected aquatic life in many Illinois lakes. According to Brown, Stall, and DeTurk (1947), the rate of sedimentation in Lake Decatur on the Sangamon River (a tributary stream of the Illinois River) increased 20 per cent in the 1936–46 period over the rate during the preceding 14.2 years. This increase in sedimentation rate in Lake Decatur was attributed to more intensive use of the watershed lands for intertilled row crops. In one county upstream from Lake Decatur, the area planted to corn and soybeans increased from about 39.0 per cent of the total area in 1924 to 64.5 per cent in 1943. Similar changes also have occurred on watersheds of other streams in Illinois.

The deposit of sediments in the floodplain lakes along the Illinois River has reduced the storage capacities of the lakes, and frequent resuspension of these sediment particles through the action of various forces has caused the lakes to maintain higher average turbidities than in former years. Kofoid (1903) found that Quiver Lake, adjacent to the Illinois River near Havana, Illinois, had an abundant growth of vegetation in years of low water (1894 and 1895) and that the bottom of the lake usually was visible in those years. Now, much of Quiver Lake is filled in with sediments, and the water remains too turbid for plant growth.

Since 1950 the Illinois Natural History Survey, the Illinois Department of Conservation, and the U.S. Fish and Wildlife Service have been co-operating in a fishery investigation on Lake Chautauqua (Starrett and McNeil, 1952). The present study was carried out in conjunction with this project.

Materials and Methods

Turbidity determinations were made with a Jackson turbidimeter (American Public Health Association, 1946) for 346 water samples collected at Lake Chautauqua. Turbidity readings were recorded in parts per million. Because the Jackson turbidimeter used in this investigation could not be operated to give accurate measurements of turbidity below 25 p.p.m., all turbidity readings of less than 25 p.p.m. were treated in calculations as 15 p.p.m. In 1953, at the same time water samples were being taken for use in the Jackson turbidimeter, more than 150 Secchi-disk readings were taken for determining the transparency of the water.

The abundance of higher aquatic plants in the lake was determined several times each summer during the study by estimating (from a boat) the percentage of the lake covered with vegetation. The categories used for expressing the abundance of vegetation were: 35 per cent or more of the lake covered with vegetation—"heavy"; 10 to 35 per cent—"moderate"; less than 10 per cent—"sparse"; and, "absent."

Only general observations were made in this investigation on plankton and its effect upon the turbidity of the lake. Turbidities of over 150 p.p.m. were caused largely by resuspended sediment particles in the water.

[1] We wish to express our appreciation to Frank C. Bellrose of the Illinois Natural History Survey for advising us in the preparation of the manuscript regarding waterfowl, aquatic plants, and historical information concerning Lake Chautauqua. Also we wish to thank George W. Bennett and R. Weldon Larimore of the Illinois Natural History Survey for critically reviewing the manuscript.

During the summer months, turbidities of less than 100 p.p.m. were sometimes caused by phytoplankton. Phytoplankton blooms in the late spring and summer months appeared to be heavier in the lake when higher plants were scarce or absent than when these plants were abundant. Kofoid (*op. cit.*) noted a similar correlation in his plankton studies of the Illinois River lakes in the Havana area.

Zooplankton apparently had little effect upon the turbidity of Lake Chautauqua.

Most of the water samples taken at Lake Chautauqua were collected at three sampling stations: one near the riverside levee (No. 10), a second near the middle of the lake (No. 11), and a third near the bluff side (No. 12), all located on a transect line that approximately bisected the lake. This transect line represented silt range 7–8 included on the map of Lake Chautauqua prepared by Stall and Melsted (1951).

Wind velocities and wind directions were recorded by a Frieze Aerovane at the Illinois Power Company at Havana, Illinois, approximately 5 miles from Lake Chautauqua. From these recordings of 1953 and 1954, average maximum wind velocities in miles per hour were calculated for periods of 1 and 5 hours preceding the time each turbidity sample was taken. The hourly maximum wind velocities were determined by averaging the maximum velocities recorded during each 15-minute period of the hour.

Dissolved oxygen determinations were made in accordance with the Winkler method (unmodified).

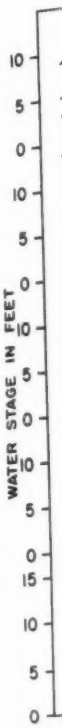
Records of the river stages at Havana, Illinois, were obtained from the "River Stage and Forecast Bulletin" issued daily except Sunday by the U.S. Department of Commerce, Weather Bureau at St. Louis, Missouri. Lake Chautauqua water-level records were furnished to us by personnel of the U.S. Fish and Wildlife Service assigned to the Chautauqua National Wildlife Refuge.

DESCRIPTION OF LAKE CHAUTAUQUA

Lake Chautauqua is located in Mason County, Illinois, within the flood plain of the Illinois River and is part of the Chautauqua National Wildlife Refuge. At normal lake stage (435.0 feet mean sea level) the lake covers a total of 3,562 acres, is between ½ and 1½ miles wide, and over 6 miles long.

The area now covered by Lake Chautauqua was formerly a series of lakes and marshes connected with the Illinois River. In 1916 an organization called the Chautauqua Drainage and Levee District was formed, and between 1917 and 1922 this group had the water areas leveed and drained for agricultural purposes. In the fall of 1926, flood waters of the Illinois River washed out sections of the levee system and flooded the area. The District was not reclaimed. In 1936 the U.S. Biological Survey (predecessor of the U.S. Fish and Wildlife Service) initiated purchase of the area for use as a migratory waterfowl refuge. The Biological Survey had the levees repaired, and constructed spillways and control gates. With these gates, the refuge manager has been able to maintain a designated water level in the lake since 1940, except during periods of high river stages. When the Illinois River attains a 12.2-foot stage at Havana (14 feet considered flood stage), water enters the lake over spillways and levees. The river usually overflows into the lake at least once or twice each year; the duration of these high water periods varies considerably.

Lake Chautauqua is quite shallow; at normal lake stage most of the lake is between 2 and 3 feet in depth. In 1950, a sediment survey was made by Stall and Melsted (*op. cit.*) which revealed that, in 23.8 years, sedimentation had reduced the storage capacity of the lake by 18.3 per cent. The sediments were carried by the Illinois River and were deposited in the lake basin during floods. In three of four sediment samples from Lake Chautauqua analyzed by Stall and Melsted, particles of less than 20 microns made up about 80 per cent, while in the fourth sample particles of less than 20 microns made up about 64 per cent. The sediment samples ranged from 1.6 to 4.1 per cent sand, 30.7 to 54.5 per cent silt, and 29.4 to 56.2 per cent clay.



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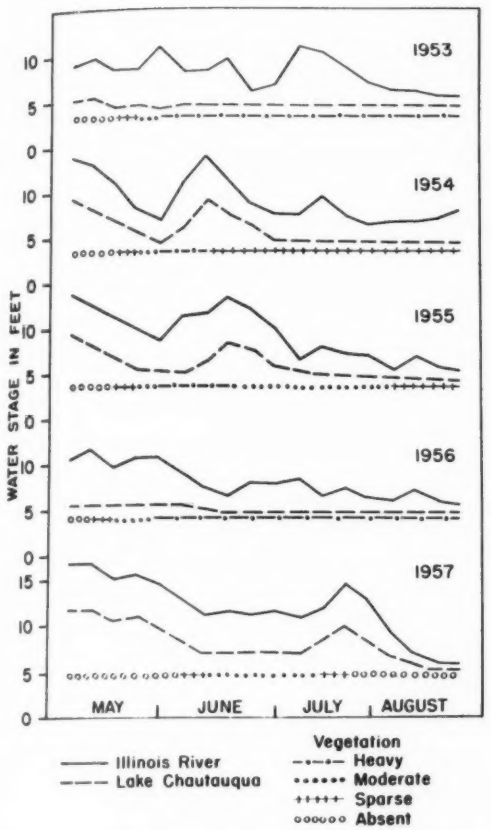

FIG. 1. Weekly average water levels at Lake Chautauqua, Illinois River stages at Havana, Illinois (May through August, 1953–57), and the abundance of sago pondweed in the lake.

Since 1926, fish have entered the lake from the Illinois River during periods of high water. Presently, 52 species have been collected and identified from the lake. The most abundant species are: gizzard shad (*Dorosoma cepedianum*), white crappie (*Pomoxis annularis*), black crappie (*P. nigromaculatus*), bluegill (*Lepomis macrochirus*), freshwater drum (*Aplodinotus grunniens*), bigmouth buffalo (*Ictiobus cyprinellus*), carp (*Cyprinus carpio*), yellow bass (*Roccus mississippiensis*), channel catfish (*Ictalurus punctatus*), emerald shiner (*Notropis atherinoides*), and spottail shiner (*N. hudsonius*).

In 1938, Bellrose (1941) found longleaf pondweed (*Potamogeton americanus*) and coontail (*Ceratophyllum demersum*) to be the most abundant plants in Lake Chautauqua. These species are now rare or completely absent from the lake. Bellrose (pers. comm.) believes that these plants have been adversely affected by the sedimentation that has occurred in the lake at an increased rate since 1943. Sago pondweed (*Potamogeton pectinatus*) is the only submergent plant that now grows abundantly in Lake Chautauqua; however, its abundance varies considerably from year to year and occurs in the lake only during the warmer months.

VEGETATION AND WATER DEPTH

The annual abundance of sago pondweed at Lake Chautauqua was found to vary with water depth during the growing season (Fig. 1). The depth of the lake, as mentioned above, was subject to change by the river overflowing into the lake. The best growth of pondweed occurred in years when the water depth during the growing season did not fluctuate and maximum depth was around 3 feet.

Verduin (1956) determined that the approximate depth of the euphotic zone in a lake could be calculated by multiplying Secchi-disk readings by 5. This factor was applied to the monthly average Secchi-disk readings recorded at Lake Chautauqua from May through August 1953. These monthly average depths of the euphotic zone (Table 1) reveal the importance of low stable water levels for plant growth in the lake. Bellrose (*op. cit.*) found that the average transparency of Lake Chautauqua from 1938 through 1940 was 10 inches (calculated depth of euphotic zone 50 inches), and that sago pondweed did not thrive in water over 48 inches deep and was entirely absent in water over 56 inches deep.

TABLE 1.—AVERAGE MONTHLY SECCHI-DISK READINGS AND APPROXIMATE DEPTHS OF THE EUPHOTIC ZONE AT LAKE CHAUTAUQUA IN 1953

Month	Total Number of Readings	Average Transparency in Inches	Euphotic Zone Depth in Inches
May	18	8.2	41.0
June	12	10.1	50.5
July	30	9.7	48.5
August	10	10.7	53.5

Water levels were low and stable (water depth 2.5 to 3.0 feet) at Lake Chautauqua during the 1953 and 1956 growing seasons, and in these years sago pondweed growth was heavy. In 1954 and 1955, pondweed began to appear in large stands in the lake by late May; however, in June of both years, high water levels resulted in extensive die-offs of pondweed. Fluctuating water levels prevented the growth of pondweed in May of 1957; in June and early July of that year water levels were higher than normal lake stage (water depth 4 to 5 feet) but were stable, and during this period a moderate stand of pondweed developed in the lake. Later in July the pondweed disappeared after an increase in water depth of about 2 feet (Fig. 1).

Duckweed (*Lemna* sp.) occurred commonly on the lake only in years when there was a heavy growth of sago pondweed. In recent years, an extensive bed (several miles in length) of lotus (*Nelumbo lutea*) developed along the riverside levee of the lake; however, most of this bed was eradicated during the high-water periods in May and in July of 1957.

TURBIDITY

The sediments in Lake Chautauqua are mostly of a fine texture and form a loose, flocculent "false bottom" (not similar to the type found in bog lakes) over the original lake bottom. A slight disturbance of the "false bottom" causes particles to become resuspended and so increases the turbidity of the water. According to Stall and Melsted (*op. cit.*), the largest sediment particles of Lake Chautauqua begin to settle after the disturbance ceases; however, it takes from 7 to 12 days for much of the sediment in the lake to settle to the bottom.

Turbidity of the lake ranged from less than 25 to 800 p.p.m. (Table 2); Secchi-disk readings varied from 2.4 inches (600 to 800 p.p.m. turbidity) to 17.7 inches (less than 25 p.p.m. turbidity).

WIND VELOCITY AND TURBIDITY

An attempt was made in the present investigation to correlate turbidity caused by resuspended particles with combinations of wind velocity, wind direction, water depth, water temperature, and absence or presence

TABLE 2.—SUMMARY OF 346 TURBIDITY DETERMINATIONS AT LAKE CHAUTAUQUA, 1953–57

Sampling Period	Number of Samples	Number of Sampling Days	Average Turbidity in p.p.m.	Range of Turbidity in p.p.m.
1953				
Mar. 27–June 20	59	21	171	36 to 700
June 27–Sept. 12	56	12	96	–25[1] to 440
Sept. 20–Dec. 19	59	12	108	–25 to 800
Sept. 20–Nov. 14	44	8	62	–25 to 145
Nov. 21–Dec. 12	11	3	313	135 to 800
Dec. 12–Dec. 19[2]	4	2	53	26 to 86
1953–54				
Dec. 22–Mar. 13[2]	17	9	161	–25 to 700
Dec. 22–Mar. 13[3]	11	6	30	–25 to 44
Dec. 22–Mar. 13[4]	6	3	399	110 to 700
1954				
Mar. 27–June 18	23	8	99	38 to 280
June 24–Sept. 24	34	9	120	–25 to 210
1955				
June 16–Aug. 24	18	9	111	–25 to 260
1957				
Sept. 26	4	1	262	215 to 350

[1] Less than 25 p.p.m.
[2] Partial ice cover when samples were collected.
[3] Ice cover when samples were collected.
[4] No ice cover when samples were collected.

TABLE 3.—TURBIDITY IN RELATION TO WIND VELOCITY AT LAKE CHAUTAUQUA

Average Maximum Wind Velocities in Miles Per Hour	AVERAGE TURBIDITY IN P.P.M				
	Spring[1] 1953	Spring[2] 1954	Summer[3] 1953	Winter[4] 1953–54	Winter and Late Fall[5] 1953–54
1.1–4.0	—	—	50	—	—
4.1–8.0	—	—	64	—	250
8.1–12.0	174	—	37	31	225
12.1–16.0	162	66	54	15	600
16.1–20.0	246	67	57	—	513
20.1–24.0	233	—	78	40	—
24.1–28.0	207	—	74	—	550
28.1–32.0	463	167	—	—	—
32.1–36.0	700	—	—	—	—

[1] Vegetation absent; ice cover absent; depth 2.2–4.7; 26 determinations.
[2] Vegetation absent; ice cover absent; depth 5.9–8.1; 10 determinations.
[3] Vegetation present; ice cover absent; depth 1.6–3.9; 58 determinations.
[4] Vegetation absent; ice cover present; depth 2.0–3.9; 10 determinations.
[5] Vegetation absent; ice cover absent; depth 1.7–3.9; 10 determinations.

of vegetation and ice cover. Lake Chautauqua has little protection from wind, and there are no islands or emergent levees in the lake to impede wave action. In the absence of rooted vegetation or ice cover, wind causes waves to arise on the lake, and white caps frequently develop. However, when rooted vegetation is abundant, only ripples develop, even during a windstorm. Chandler (1940) found that strong winds caused an increase in turbidity of western Lake Erie. In the summer of 1940, Bellrose (*op. cit.*) observed that moderate winds on Lake Chautauqua could result in the reduction of the transparency of the water from 11 to 6 inches.

An analysis of the 1953–54 wind and turbidity data failed to reveal any correlation between recorded wind direction and turbidity. Most of the wind directions used in the analysis were the prevailing wind directions and varied between southwest and northwest.

Shallow water, no vegetation.—In the spring months of 1953, vegetation was absent from the lake, and water depths at the principal sampling stations ranged from 2.2 to 4.7 feet. Turbidity during this season tended to vary with wind velocity (Table 3). The relationship between wind velocity and turbidity at two sampling stations on Lake Chautauqua throughout an 18-hour period on May 1 and 2, 1953, is illustrated in Fig. 2. During the night of May 1 and the morning of May 2, the wind diminished and within a 4.5-hour period (from 11:00 P.M. to 3:30 A.M.) the turbidity at station No. 12 decreased 60 p.p.m. Soon after this observation, the wind picked up again, and within about 8 hours the turbidity increased 120 p.p.m. It will be noted in Fig. 2 that average maximum wind velocity during the 1-hour period preceding sampling was better correlated with turbidity than the average maximum 5-hour velocity preceding sampling (water temperature 18°C.).

On September 26, 1957, turbidity ranged from 215 to 350 p.p.m. at four Lake Chautauqua sampling stations (Table 2). The wind velocity at the time of sampling was estimated to have been between 20 and 25 miles per hour, and no vegetation was present in the lake.

In the absence of ice cover during the late-fall and winter months (1953–54), turbidity was considerably higher in the lake than it was at the same wind velocities in the spring of 1953 (Table 3). Except for water temperatures, conditions were quite similar during both periods. Since the viscosity of water increases as the temperature decreases, the colder water in the late-fall and winter period probably held the resuspended particles in suspension longer than did the warmer water in the spring period (Fig. 2). Also, the colder water

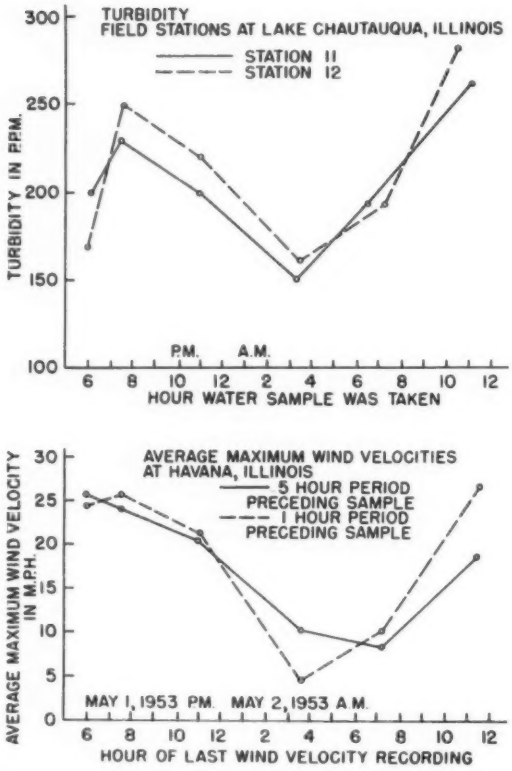

FIG. 2. The relationship between wind velocity and water turbidity at Lake Chautauqua during an 18-hour period. Vegetation was absent from the lake. Water depth at Station No. 11 was 3.5 feet and at Station No. 12 it was 4.5 feet.

probably exerted more friction on the "false bottom" than did the warmer water. Variation in viscosity of water is a possible explanation for the differences in turbidity between the spring and the late-fall and winter periods at Lake Chautauqua.

In the winter of 1953–54 when ice cover was present on Lake Chautauqua, the turbidity ranged from less than 25 to 44 p.p.m. (Tables 2 and 3). Ice cover prevented wind from having any effect on the turbidity of the lake.

Deep water, no vegetation.—Water levels were higher in the spring of 1954 than in the preceding spring (Fig. 1). Vegetation was absent from the lake in the spring of 1954. Water depths at the times of sampling ranged from 5.9 to 8.1 feet. The turbidity readings taken in the spring of 1954 indicated that average maximum wind velocities of 12.1 to 20.0 miles per hour produced little or no effect on turbidity (Table 3).

Shallow water, vegetation.—Turbidity readings for the summer months of 1953, given in Table 3, were selected to include only those that were known not to have been affected appreciably by fish activity or plankton. During this period, heavy stands of sago pondweed were present in the lake (Fig. 1). Averages of the selected turbidity readings for the summer of 1953 indicate that wind velocity had little or no effect upon the turbidity of the lake (Table 3). The studies of Irwin (1945) in Oklahoma showed that green vegetation cleared turbid water. However, at Lake Chautauqua we believe that the reduction of the physical effect of the wind by rooted aquatic vegetation was of more importance in causing low turbidity than the chemical or biological factors.

Wind velocity–turbidity relationships were calculated for the 1953 summer period by the least-squares method (Snedecor,

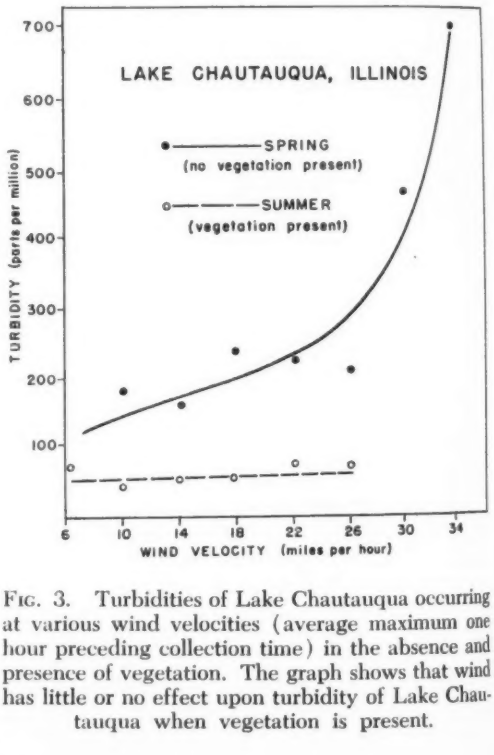

FIG. 3. Turbidities of Lake Chautauqua occurring at various wind velocities (average maximum one hour preceding collection time) in the absence and presence of vegetation. The graph shows that wind has little or no effect upon turbidity of Lake Chautauqua when vegetation is present.

1946) and estimated for the 1953 spring data. The resultant relationships (Fig. 3) reveal the effects of wind velocity on the turbidity of the lake (less than 4.8 feet in depth) in the absence and presence of vegetation. The empirical observations (Fig. 3) for the 1953 spring period are quite scattered; however, they do indicate the possibility that a sharp increase in the effect of the wind on turbidity occurs between wind velocities of 26 and 30 miles per hour. According to Hutchinson (1957:273), "Most investigators have concluded that the stress varies as some power of the wind velocity. . . ." We do not believe that the actual relationship between turbidity caused by resuspension of sediment particles and wind velocity is as close as the estimated curve indicates. This doubt is based upon Benedict's (1946) findings on the Iowa River that turbidity determinations do not accurately express the concentrations of suspended sediment.

High River Stages

In June of 1954 and 1955, the Illinois River overflowed parts of the riverside levee at Lake Chautauqua. During these periods, the lake was muddy in appearance only in the immediate areas where the river water was coming into the lake. A series of water samples was collected on June 16, 1955, in the lake near the levee where the river water was flowing into the lake, Table 4 (river stage at Havana was 13.2; crested the following day at 13.3 feet). About 35 feet out in the lake from the levee, the current was rather swift and the turbidity there was 74 p.p.m. The current was slightly discernible at about 80 yards out in the lake, and at about 100 yards there was no noticeable current. Approximately 300 yards out from the levee, the turbidity was 47 p.p.m., a reading that was just slightly higher than recorded at the three principal sampling stations on the lake. All the water samples were collected within 1 hour, and the lake during this time was calm. Other than in the immediate area of the overflow, the turbidity of the lake was not affected by moderately high river stages.

TABLE 4.—TURBIDITY OF LAKE CHAUTAUQUA DURING MODERATELY HIGH RIVER STAGES IN JUNE 1954 AND IN JUNE 1955[1]

Stations	TURBIDITY (IN P.P.M.)	
	1954	1955
Riverside levee (No. 10)	63	33
Middle of lake (No. 11)	77	37
Bluffside (No. 12)	52	32
Overflow near riverside levee (No. 10)	132	—
35 feet from overflow	—	74
100 yards from overflow	—	68
200 yards from overflow	—	65
300 yards from overflow	—	47

[1] Water depth ranged from 5.5 feet to 9.5 feet.

The overflow water coming into Lake Chautauqua from the river in both years flowed through a small lake lying between the river and the riverside levee. At the moderately high river stages during which turbidity readings were made, we believe that much of the sediment load of the river was deposited in the small lake. Frank C. Bellrose (pers. comm.) stated that during the extremely high water periods of 1943 and 1944, the levees at Lake Chautauqua were completely topped by the river, current was present through the lake, and most of the lake had the same muddy appearance as the river. He also observed in several years subsequent to 1944 that the river side of the lake had a muddy appearance during high river stages. According to Mitchell (1954), gauge height of the river at Havana was 27.3 feet in 1943 and 23.3 feet in 1944. The highest gauge reading at Havana since 1944 was 21.0 feet in 1950.

Fish Activity

The majority of the fishes that occur in Lake Chautauqua probably feed at some time or another in their lives upon bottom organisms. Such feeding activities disturb the "false bottom" and cause sediment particles to become resuspended and thereby affect the turbidity of the lake.

High turbidities in shallow midwestern lakes are often attributed to the rooting habits of carp. At Lake Chautauqua carp was the only species of fish actually seen

TABLE 5.—COMPARISON OF COMMERCIAL SEINE-HAUL CATCHES FROM DIFFERENT SECTIONS OF LAKE CHAUTAUQUA, ILLINOIS[1]

Kind of Fish	POUNDS PER 100 YARDS OF SEINE			
	Lower Lake	Bluff-side	Middle	River-side
Carp	33.4	12.5	19.8	144.9
Buffalo	206.6	278.4	153.2	143.2
Drum	76.2	132.0	109.8	73.7
Catfish	25.9	12.3	19.2	24.2

[1] A total of 266,760 yards of seine was employed; seine hauls were made each September from 1951 through 1957.

disturbing the lake bottom, and most of the observed carp activity was confined to the riverside section of the lake. Also each year in the September commercial seining program at the lake, carp were more abundant in the hauls made on the riverside than elsewhere in the lake (Table 5). In the warmest months of 1953, turbidity likewise was usually higher at the riverside sampling station than at the middle-of-lake and bluffside stations (Table 6). Turbid conditions of the lake in the warmest months of 1953 were largely due to the activity of carp and other fishes and to a lesser extent to phytoplankton.

Turbidity caused by fish activity tended to vary considerably throughout the warmest months of 1953, and usually most of the fish activity that affected the turbidity of the lake probably was a result of fish feeding on the bottom. An exception to this was observed on the morning of July 9, 1953. At 5:30 on that morning, an abnormal amount of fish activity was seen at the riverside station No. 10. Turbidity there was 440 p.p.m., and transparency of the water was 2.8 inches. The dissolved-oxygen content of the water at this station was only 2.0 p.p.m., water temperature 24°C., and *p*H 8.4. Ten minutes later, station No. 11 (middle-of-lake) was visited, and there very little fish activity was noted: The turbidity was 138 p.p.m., water transparency 6.7 inches, and dissolved oxygen 3.9 p.p.m. Approximately ½ mile up the lake from station No. 11, the turbidity was 160 p.p.m., and no fish activity was observed. About 1 mile up the lake from station No. 11 at 6:20 A.M., some fish activity was seen, the turbidity there was 290 p.p.m., and the dissolved-oxygen content of the water was only 1.6 p.p.m. Later that morning some dead fish were found in this same vicinity, and careful examination of several dead fish revealed that they had died from asphyxiation. The fish kill in the lake was very localized.

The weather conditions on July 9 were warm and still, and it is not uncommon under such conditions for a rich shallow lake supporting a heavy growth of plants (including phytoplankton) to show an oxygen pulse. An oxygen pulse was noted at Lake Chautauqua on June 20, 1953, when at station No. 12 (bluffside) the dissolved-oxygen content at 9:25 A.M. was 2.8 p.p.m. and by late afternoon that day it was 6.6 p.p.m.

In the late afternoon of July 9 no fish activity was seen at station No. 10—the turbidity there had dropped to 140 p.p.m.; at station No. 11, 130 p.p.m. and at station No. 12, 155 p.p.m. Dissolved oxygen was not determined in the afternoon; but we believe that, since it was a sunny day, sufficient oxygen for fish life was being derived from the plants in the lake.

Ellis (1937) considered 3 p.p.m. of dissolved oxygen at 25°C. to be the upper limit at which asphyxia of fresh-water fish could be expected. According to Plehn (1924), suffocating fish sometimes display excitement and dash about furiously, which was the way the fish acted at station No. 10 on the morning of July 9, 1953. We believe that

TABLE 6.—AVERAGE AND RANGE OF 57 TURBIDITY DETERMINATIONS IN P.P.M. AT LAKE CHAUTAUQUA MAY 20 THROUGH OCTOBER 29, 1953

Station	MAY 20–JULY 9		JULY 25–OCTOBER 31		MAY 20–OCTOBER 31	
	Average	Range	Average	Range	Average	Range
Riverside (No. 10)	180	64–440	61	35–75	124	35–440
Middle (No. 11)	108	36–138	89	55–175	99	36–175
Bluffside (No. 12)	94	38–155	73	60–95	84	38–155

the abnormal fish activity observed at Lake Chautauqua that morning was related to the reduced dissolved-oxygen content of the water.

DISCUSSION

The disturbance of the "false bottom" of the lake by fish and water motion (wind) account for high turbidities observed in Lake Chautauqua. Ice cover, vegetation, or water depth exceeding 5.8 feet will drastically reduce or eliminate the effect that wind-produced water motion has on the turbidity of the lake. However, these conditions do not govern the fish activity that does affect the turbidity of the lake. According to Cahoon (1953), the removal of over 1,600,000 pounds of carp and 95,000 pounds of catfish, largely over a 5-year period, from 20,000-acre (minimum size) Lake Mattamuskeet, North Carolina, resulted in a gradual increase in transparency from 6 inches to 3 or 4 feet. Between 1950 and 1957, a total of 2,022,965 pounds of commercial fishes, including 417,245 pounds of carp, were removed by commercial fishermen from 3,562-acre Lake Chautauqua. After commercial fish were removed from the lake, the growth of vegetation was not increased and turbidity was not reduced. The effects of the commercial removal of fish from the lake may have been largely nullified by some recruitment of fish from the river, and more importantly, by fish spawned in the lake.

Various workers have reported the changes occurring in turbidity of lakes after the fish populations were drastically reduced or completely eradicated. Thompson and Bennett (1939) found in Illinois that lakes cleared up after the removal of carp, buffalo, suckers, catfish, and certain forage species. Weier and Starr (1950) reported that it was possible to see the bottom in 3 feet of water in an Ohio marsh 3 weeks after the carp had been killed by rotenone. Prior to the removal of fish from this marsh, Anderson (1950) found that a 10-centimeter Secchi disk disappeared at 10 inches. Turbidity of Lake Chautauqua also would be reduced if, during an extensive period of low water levels, most of the fish were eradicated. It would not be difficult under such water conditions to eliminate with rotenone most of the fishes in the lake. However, the benefits of such an operation would be temporary, since existing levees could not prevent the river from eventually overflowing into the lake. The fluctuating water levels caused by the river, combined with the entry of river fishes into the lake, would soon adversely affect plant growth and the turbidity of the lake.

High water levels at Lake Chautauqua are controlled by the amount, intensity, and distribution of precipitation on the watershed of the Illinois River above Liverpool, Illinois. The present average rate of about 3,100 cubic feet per second of water diverted from Lake Michigan (including domestic pumpage) into the Illinois River is only a minor factor in affecting the water levels at Lake Chautauqua.

The sediment carried by the river and deposited in the lake is derived mainly from the tilled land of the river's watershed. Larson, Smith, Sauer, and Melsted (1951) estimated that a complete watershed-conservation program, as described by them, would reduce the rate of siltation in Lake Bracken, Illinois, by 84.0 per cent. The conservation watershed program proposed by Stall, Klingebiel, Melsted, and Sauer (1951) for the West Frankfort Reservoir, Illinois, would reduce the present rate of siltation there by about 80.0 per cent. Following an extremely intense rainfall of up to 13 inches in 6 hours on the watershed of the Mackinaw River, a tributary stream of the Illinois River, Hall (1952) determined that conservation practices had reduced soil losses in cultivated fields by 85.5 per cent. Studies such as these reveal the importance of complete watershed-conservation programs in reducing sedimentation in Illinois waters. The current rapid rate of sedimentation of Illinois lakes not only decreases storage capacities of these lakes but results in high turbidities, as was shown in the foregoing sections of this paper.

Fishery and bottom-fauna studies conducted at Lake Chautauqua indicate that

the lake is quite productive. The growth rate of fishes in the lake is good (Starrett, unpubl.). The high productivity of this turbid lake is probably related to the nutrients added to the lake intermittently by the river and the excreta deposited by thousands of waterfowl that rest on the lake during the late fall months of each year. Furthermore, almost the entire lake is within the euphotic zone at normal lake stage, which is often the condition through much of the growing season (Fig. 1 and Table 1). Also, no period of summer stagnation is known to have occurred in the lake.

Fluctuating water levels caused by the river have been considered as being an important factor in preventing overpopulations of fish in Lake Chautauqua. This subject has been discussed as drawdowns for other waters by Wood (1951), Bennett (1954), and others.

The fluctuating water levels and sedimentation in the lake caused by the overflow of the river into the lake have had an adverse effect upon the vegetation of the lake. Under present conditions no submerged plants are available to waterfowl on the lake after October, even in years of heavy stands of sago pondweed. At Lake Chautauqua, sago pondweed was abundant in October 1956 and absent from the lake in 1957. Frank C. Bellrose (pers. comm.) furnished us with his weekly aerial counts of baldpates (*Anas americana*) at Lake Chautauqua in October 1956 and 1957. In October 1956, a total of 322,000 duck-days were spent on the lake by baldpates in contrast to only 525 duck-days in 1957. Bellrose believes the decrease in baldpate use of the lake in 1957 was chiefly due to the absence of sago pondweed.

Even though Lake Chautauqua lacks natural duck-food plants in late fall, it still serves an important function as a resting area for large concentrations of waterfowl, particularly mallards (*Anas platyrhynchos*). Most of these ducks find their feed in neighboring mechanically picked cornfields (Bellrose, 1954).

Fishing success for largemouth bass (*Micropterus salmoides*) and yellow perch (*Perca flavescens*) has declined at Lake Chautauqua since 1943 (Starrett and McNeil, *op. cit.*). Very few perch and bass are taken now in nets and seines fished in the lake. These species were probably adversely affected by sedimentation and turbidity. Some other species were evidently benefited by the changes that occurred, and such species perhaps depressed bass and perch populations through interspecific competition.

Presently, the lake provides anglers with good fishing for bluegills, crappies, freshwater drum, and yellow bass. Between 1950 and 1954, the annual average rate of pole-and-line catch ranged from 0.6 to 0.8 fish per fisherman-hour (Starrett, 1958). Some anglers have been successful in catching channel catfish on trot lines.

Commercial fishing at Lake Chautauqua is of some importance to local fishermen. The reported commercial catch at the lake in 1954 was worth over $32,000.00 [based on local, wholesale undressed prices] (Starrett, *op. cit.*). Large sport and commercial fish populations can be maintained in the lake, provided that future losses in water depth due to sedimentation are compensated for by an increase in the height of the normal lake stage.

SUMMARY

At Lake Chautauqua, Mason County, Illinois, between 1953 and 1957, 346 turbidity determinations were made with a Jackson turbidimeter and 156 water-transparency readings were taken with a Secchi disk. Turbidity of the lake ranged from less than 25 p.p.m. to 800 p.p.m. The resuspension of sediment particles, which were originally carried and deposited in the lake by flood waters of the Illinois River, caused the high turbidities at Lake Chautauqua. The disturbance of the lake bottom by fish and/or water motion produced by wind caused sediment particles to become resuspended. Wind velocity had little or no effect upon turbidity when vegetation or ice cover was present in the lake or in areas where depth of the water exceeded about 5.8 feet. When depths of the lake were less than 4.8

feet and vegetation or ice cover was absent, turbidity tended to vary with wind velocity. During periods when wind had little or no effect upon turbidity, fish activity and to a lesser extent phytoplankton usually prevented the lake from becoming clear. Over an 8-year period, the removal of 2,022,965 pounds of fish from the lake by commercial fishermen had no apparent effect upon vegetation growth or turbidity. During moderately high river stages, turbidity was affected only in areas where the river water was overflowing into the lake. Important duck-food plants that were formerly abundant were adversely affected by sedimentation and fluctuating water levels. Changes had also occurred in the species composition of the fishes. The shallowness of Lake Chautauqua through much of the growing season assured that most of the lake was within the euphotic zone, and this was considered to be an important factor in the high productivity of this turbid, fertile lake.

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FOOD HABITS OF THE RED FOX IN MISSOURI[1]

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The state-wide study reported here had three principal objectives: (1) to learn the general feeding habits of Missouri's red foxes (*Vulpes fulva*); (2) to learn the extent and effect of red fox feeding upon other managed wildlife species; and (3) to learn the extent of red fox predation upon poultry and livestock.

The red fox, Missouri's most abundant and widely known wild member of the dog family, is found throughout the state, but is most common north of the Missouri River. The years 1947–54 were a period of great fox abundance in Missouri. No accurate population estimates are available for year-to-year comparison, but information most indicative of trends is the percentage of red foxes taken by farmers trained under the extension predator-control program in Missouri. During the fiscal year beginning July 1, 1949, red foxes comprised 50.7 per cent of the total catch of all predators taken in this program. This percentage increased to 54.6 per cent in 1950–51, and reached the all-time high of 68.0 per cent during 1951–52. The percentages later declined to levels of 66.0, 57.5, and 56.9 per cent, respectively, for successive years (Sampson, 1956). These data reflect directly the relative density of red fox in comparison to that of gray fox (*Urocyon cinereoargenteus*), and coyote (*Canis latrans*), but they probably also serve as a rough measure of population trends in the red fox.

This investigation was begun during the fiscal year 1949–50 and continued for five years. A total of 130 hunter and trapper co-operators were supplied with equipment for the preservation of predator stomachs. Materials were preserved and examined according to standard methods, as described in detail in an earlier paper (Korschgen, 1957).

REVIEW OF LITERATURE

The food habits of the red fox have been investigated rather thoroughly in the eastern United States, and to a lesser extent in the Midwest and elsewhere (Table 1). Previous studies show that, in general, the feeding habits of red foxes do not materially affect prey populations of either mammals or birds. Murie (1936), Scott (1943), and Richards and Hine (1953) all report, in effect, that fox predation does not exert a dominant influence on game populations, even though many game animals are eaten. In New York, Darrow (*in* Seagears, 1944: 24–37) and Cook and Hamilton (1944) found that game birds were of little importance in the red fox diet. Swink (1952)

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TABLE 1.—SUMMARY OF RED FOX FOOD-HABITS LITERATURE

Location	No. and Kind of Samples	Principal Foods	Reference
Michigan	300 scats	Mammals, birds, insects	Dearborn (1932)
Michigan	Trails	Cottontails, voles, insects	Murie (1936)
New York	206 stomachs	Mice, rabbits, grasses	Hamilton (1935)
New York	313 scats	Field mice, rabbits	Eadie (1943)
New York	134 stomachs	Rabbits, mice	Darrow (*in* Seagears, 1944)
New York	537 scats	Cottontail, fruit, mice	Cook and Hamilton (1944)
New York	400 scats	Deer, mice, fruits	Schueler (1951)
Pennsylvania	147 stomachs	Cottontail, woodchuck, deer	English and Bennett (1942)
Pennsylvania	147 stomachs	Chicken, rabbits, pheasants	Latham (1950)
Iowa	1,454 scats	Cottontails, mice	Scott (1943)
Iowa	991 scats	Cottontails, rodents	Scott (1947)
Iowa	1,450 scats	Rabbits, mice, birds	Scott and Klimstra (1955)
Indiana	211 stomachs	Rabbits, mice	Kase (1946)
Ohio	89 stomachs	Opossum, rabbits, squirrels	Gier and Gale (1946)
North Dakota	200 stomachs	Mice, game birds, rabbits	McKean (1947)
Virginia	549 scats	M. mouse, cottontail, opossum	Swink (1952)
Wisconsin	59 stomachs	Rodents and rabbits	Richards and Hine (1953)

reported similar findings in Virginia. In contrast, Gier and Gale (1946) reported that the game consumption of foxes in Ohio cuts heavily into the hunters' take, while Schueler (1951) concluded that red fox feeding habits in New York were economically neutral.

Availability of foods appears to be the key to feeding habits of the red fox. Scott (*op. cit.*) reported that fluctuations in the frequency of occurrences of some foods, for which no appreciable change in availability was evident, resulted simply because other foods became more or less available. Later, Scott and Klimstra (1955) concluded that fox feeding trends automatically responded to seasonal changes in the relative availability of foods. According to Cook and Hamilton (*op. cit.*), fruits predominate in the red fox diet during summer, flesh in winter. Dearborn (1932) found great differences in amounts of mammals, birds, and fruits taken by Michigan foxes in successive years.

Other studies that revealed much the same information were reported upon by Nelson (1933) and Handley (1934) in Virginia, Errington (1935) in Iowa, Hatfield (1939) in Minnesota, MacGregor (1942) in Massachusetts, and Llewellyn and Uhler (1952) in Maryland.

RESULTS AND DISCUSSION

Among the 1,170 red fox stomachs examined during this study, 1,006 contained measurable amounts of food, and 164 (14.0 per cent) were empty, or contained only debris and nonfood items. The majority of stomachs were collected from 1949 to 1954. Distribution of the sample, by county, is shown in Fig. 1.

A total of 63 kinds of animals, 21 plants, and 2 miscellaneous items were identified in the stomach contents (Table 2). Only 15 animals and one plant food (persimmon fruits) each contributed 1.0 per cent or more to the diet. The data are most representative of the winter foods, since comparatively few samples were obtained for the other seasons. Data for the summer are least well represented, since few people attempt to take foxes during the summer.

Principal Foods

Rabbits, mostly cottontails, were the foods most heavily utilized by red foxes during the years of this study. Three occurrences of domestic rabbit and two of jack rabbit contributed to the diet, but individually were unimportant items. Collectively, rabbits were found in about two-fifths of the stomachs examined, and make up 36.8 per cent of the total food volume.

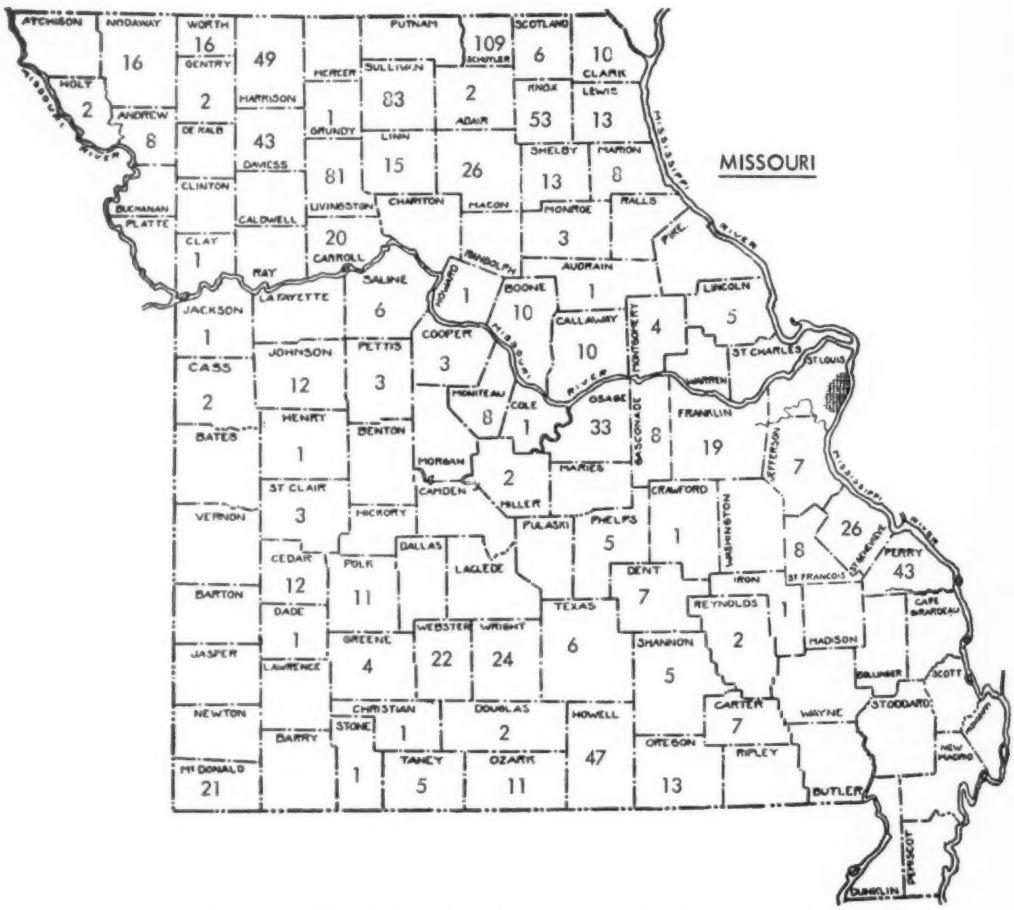

FIG. 1. Distribution of 1,006 red fox stomachs, by county.

Small rodents (mice and rats) provided the second most important source of food for red foxes, as 22.0 per cent of the total bulk. Meadow mice were eaten with greatest frequency and provided the greatest bulk of small rodents. Cotton rats occurred only in the southern part of the state, so that their state-wide average is not truly indicative. White-footed mice occurred more frequently than did cotton rats, but did not account for as great a volume. Lemming mouse and four other species made up the remainder of this category of foods.

Poultry of five kinds constituted 13.7 per cent of the red fox diet, for third rank. Chicken accounted for the bulk of this type of food, but a part of this item undoubtedly was carrion that could not be identified as such. Most fox food-habits studies from other states report poultry taken in small amounts. A notable exception is that of Latham (1950), who reported that domestic chickens and ducks constituted about 32 per cent of the year-around red fox diet in a southeastern Pennsylvania study. Most reports in the literature range from a "trace" to about 10 per cent for the poultry category.

Other mammals, including squirrels, house cat, opossum, raccoon, skunks, woodchuck, muskrat, shrews, pocket gopher, dog, and mole, occurred in about one of every ten samples, and accounted for 7.7 per cent of the diet, by volume. Fox squirrel, house cat, opossum, and raccoon each were taken in amounts of 1.0 per cent or more each.

Carrion (7.7 per cent) was the fifth most important category of food, and consisted of a variety of livestock, poultry, and game

items, obviously not freshly killed prey. Carrion often could be identified from the condition of flesh, hair, feathers, or the presence of maggots.

Livestock, represented by pig, sheep, calf, and goat amounted to slightly more than 5 per cent of the five-year diet. Pig was the most important and most frequently taken item. Lamb occurred in 19 stomachs, calf in one, and goat in three. Some occurrences may have been carrion, but most appeared to have been young animals that could have represented fresh kills.

Birds of many kinds, chiefly songbirds and unclassified, occurred frequently, but in small amounts. Several species were tentatively identified, and included bobwhite quail (*Colinus virginianus*), cardinal (*Richmondena cardinalis*), meadowlark (*Sturnella* sp.), red-winged blackbird (*Agelaius phoeniceus*), yellow-shafted flicker (*Colaptes auratus*), eastern bluebird (*Sialia*

TABLE 2.—STOMACH CONTENTS OF 1,006 RED FOXES IN MISSOURI, 1949–54

Food Item	Per Cent by Occurrence	Volume[1]
RABBITS	(39.3)	(36.8)
Cottontail (*Sylvilagus floridanus*)	38.8	36.1
Domestic (*Lepus cuniculus*)	0.3	0.4
Jack rabbits (*Lepus* spp.)	0.2	0.3
MICE AND RATS	(51.4)	(22.0)
Meadow mouse (*Microtus ochrogaster*)	30.0	13.5
Cotton rat (*Sigmodon hispidus*)	5.0	3.0
White-footed mouse (*Peromyscus* sp.)	8.7	1.8
Lemming mouse (*Synaptomys cooperi*)	3.1	1.5
Pine mouse (*Pitymys nemoralis*)	0.7	0.7
House mouse (*Mus musculus*)	2.5	0.7
Harvest mouse (*Reithrodontomys* sp.)	2.4	0.5
Mouse, unclassified	4.3	0.2
Norway rat (*Rattus norvegicus*)	0.4	0.1
POULTRY	(13.6)	(13.7)
Chicken (*Gallus gallus*)	11.9	12.3
Mallard duck (*Anas platyrhynchos*)	0.8	1.0
Turkey (*Meleagris gallopavo*)	0.3	0.4
Ducks, unclassified	0.3	trace
Guinea fowl (*Numida meleagris*)	0.3	trace
OTHER MAMMALS	(10.4)	(7.7)
Fox squirrel (*Sciurus niger rufiventer*)	2.9	2.4
House cat (*Felis domestica*)	0.6	1.5
Opossum (*Didelphis marsupialis*)	1.2	1.2
Raccoon (*Procyon lotor*)	0.8	1.1
Skunk (*Mephitis mephitis*)	0.4	0.3
Woodchuck (*Marmota monax*)	0.5	0.3
Muskrat (*Ondatra zibethicus*)	0.3	0.2
Short-tailed shrew (*Blarina brevicauda*)	0.9	0.2
Gray squirrel (*Sciurus carolinensis*)	0.8	0.2
Pocket gopher (*Geomys bursarius*)	0.1	0.1
Dog (*Canis familiaris*)	0.1	0.1
Least shrew (*Cryptotis parva*)	1.7	0.1
Mole (*Scalopus aquaticus*)	0.1	trace
Spotted Skunk (*Spilogale interrupta*)	0.1	trace
CARRION	6.3	7.7
LIVESTOCK	(7.5)	(5.1)
Pig (*Sus scrofa*)	5.2	3.9
Sheep (*Ovis aries*)	1.9	1.1
Calf (*Bos taurus*)	0.1	0.1
Goat (*Capra hircus*)	0.3	trace
BIRDS	(14.7)	(3.4)
Quail (*Colinus virginianus*)	2.4	1.9
Songbirds	7.7	0.8
Birds, unclassified	4.1	0.3
Crow (*Corvus brachyrhynchos*)	0.5	0.2
Short-eared owl (*Asio flammeus*)	0.1	0.2
INVERTEBRATES	(6.1)	(0.7)
Short-horned grasshoppers (Acrididae)	4.0	0.5
Scarab-beetles (Scarabaeidae)	1.3	0.1
Long-horned grasshoppers (Tettigoniidae)	0.8	0.1
Ground-beetles (Carabidae)	1.4	trace
11 other kinds of insects, each in "trace" amount		
UNDETERMINED ANIMAL MATTER	1.1	0.1
FISH AND REPTILES	0.8	trace
PLANT FOODS	(21.8)	(2.7)
Persimmon (*Diospyros virginiana*)	5.6	1.3
Grass and sedge leaves	13.8	0.7
Hickory nuts (*Carya* sp.)	1.0	0.2
Grapes (*Vitis* spp.)	0.7	0.1
Corn (*Zea Mays*)	0.4	0.1
Pear (*Pyrus communis*)	0.4	0.1
White-mulberry (*Morus alba*)	0.1	0.1
Strawberries (*Fragaria* sp.)	0.1	0.1
13 other plant foods, each in "trace" amount		
MISCELLANEOUS (paper, string)	0.4	trace

[1] The total volume examined was 44,315 cc.

TABLE 3.—STOMACH CONTENTS OF 1,006 RED FOXES IN MISSOURI, BY YEAR, 1949–54

	PERCENTAGES BY OCCURRENCE[1] AND VOLUME									
Fiscal Year	1949–50		1950–51		1951–52		1952–53		1953–54	
No. of Stomachs	201		241		277		178		109	
Total cc. Studied	7,256		10,554		12,969		9,714		3,822	
Food Group	*Occ.*	*Vol.*	*Occ.*	*Vol.*	*Occ.*	*Vol.*	*Occ.*	*Vol.*	*Occ.*	*Vol.*
Rabbits	39.8	37.7	36.5	35.3	37.5	37.8	34.8	29.3	56.0	54.9
Mice and rats	49.3	20.6	57.7	24.3	60.3	28.5	44.9	27.3	29.4	7.9
Poultry	10.4	4.2	14.9	17.3	10.1	9.9	19.1	24.1	16.5	8.8
Other mammals	7.0	9.3	12.4	4.9	7.6	8.2	13.5	8.7	13.8	7.0
Carrion	4.0	6.3	5.4	7.9	4.0	4.6	10.1	11.7	11.9	10.5
Livestock	13.4	14.8	8.7	4.4	4.7	3.3	4.5	1.9	5.5	2.2
Birds	18.4	3.6	14.1	2.5	14.1	3.7	15.2	3.2	10.1	3.0
Invertebrates	7.5	0.3	3.7	0.9	5.1	0.4	9.6	0.9	5.5	1.4
Undetermined animal	2.5	0.6	—	—	0.7	tr.	1.1	0.2	1.8	0.1
Fish and reptiles	1.0	0.1	1.2	tr.	0.7	0.1	—	—	—	—
Plant foods	18.4	2.5	16.6	1.9	21.3	3.5	26.4	2.7	33.0	4.0
Miscellaneous	—	—	0.8	tr.	0.7	tr.	—	—	—	—

[1] These percentages have been carried one digit past the decimal point for comparative purposes only.

sialis), and slate-colored junco (*Junco hyemalis*). Quail made up the largest bulk of this type of food, although songbirds appeared more often. Five occurrences of crow and one of short-eared owl may not have represented fresh kills by the animals involved.

Invertebrates of 15 kinds, mostly grasshoppers and June-beetles, made up 0.7 per cent of the diet. The bulk of these were taken during summer.

Plant foods of 21 kinds occurred in the stomach contents. Persimmon fruit accounted for nearly one-half of all plant foods. Grass leaves occurred frequently, but usually in small amounts, and may have been ingested incidentally. Other plant foods were unimportant.

Annual Variations in Foods

Missouri's rabbit population showed a general decline in numbers from 1949 to 1953, as indicated by the annual state-wide rabbit census taken each July by personnel of the Missouri Conservation Commission (Wight, 1959). Wight's indices of rabbits per mile of census route for these years were as follows: 0.64, 0.62, 0.55, 0.40, and 0.38.

The volumetric percentages of rabbit in the red fox diet during these years were: 37.7, 35.3, 37.8, 29.3, and 54.9 per cent, respectively (Table 3).

Statistical analyses demonstrated a barely significant relationship between the rabbit-population index and consumption of rabbits by foxes during the 5-year period. Correlation coefficients were 0.57 between population index and volume of rabbit in the red fox diet, and 0.49 between population index and occurrence of rabbit. These correlations are little more than one-half that shown for coyotes and rabbits (Korschgen, *op. cit.*). The differences may be partially attributed to the relatively greater importance of small rodents as staples in the red fox diet. Scott and Klimstra (*op. cit.*), working in southeastern Iowa, also found that a general decline in the cottontail population was not accompanied by a corresponding decline in the proportion of cottontail in the fox diet.

The increased take of rabbit, as more than one-half of all foods, by volume, during 1953–54 suggested a possible build-up in the rabbit population, in spite of the above-mentioned correlations. Wight's (*op. cit.*) census data for 1954 proved unreliable as a result of extreme weather conditions during the census period. Subsequent indices, however, further indicated a rising rabbit population, with 0.74 rabbit per mile of census route in 1955 and 1.26 per mile in 1956. Other factors that undoubtedly played a part in the increased take of rabbits during

1953–54 were poor ground cover caused by a severe drought, and a very low population of small rodents, as shown by field observation.

Mice were very important in the red fox diet each year from 1949–50 to 1952–53. The figures do not clearly reflect the exceptionally high mouse populations that occurred, especially in northern Missouri, during 1951. Observations and reports from field personnel showed that high mouse populations had existed in southern and central Missouri during the preceding two seasons, which tended to level state-wide average figures. Reports indicated, however, that the mouse irruption of northern Missouri was more intense and widespread than that farther south.

Cotton rat was never found in samples collected north of the Missouri River, but during the population irruption of this species, consumption by red foxes was very high in southwestern Missouri. Examination of 11 red fox stomachs from the southwestern counties during 1949–50 showed an incidence of 73 per cent cotton rat, which made up 83.5 per cent of all foods eaten by foxes from that area. Utilization decreased in 1950–51, when cotton rats occurred in 50 per cent of the 44 stomachs examined, and made up 52.0 per cent of the food volume. Further reduction was evident in 1951–52, when cotton rats were identified in 10 per cent of 60 stomachs, and comprised 8.5 per cent of the bulk. Thereafter, only one occurrence of cotton rat was recorded, and co-operators unanimously agreed that the cotton rats were gone.

The amount of poultry in the diet varied considerably year to year, from a low of about 4 per cent, to a high of 24 per cent. The greatest quantity of poultry was found during 1952–53, when the foxes' principal food (rabbit) was least available.

Items in the other mammal category, except fox squirrels, were found infrequently, and consequently did not show major annual variation in amounts consumed. Carrion also was infrequently taken, but its use nearly doubled during the last two years. It appeared that carrion was substituted for rabbits in the low years of 1952–53, and for mice after their population decline the following year.

An unusually large proportion of pig found in the stomachs during 1949–50 raised the livestock total to nearly 15 per cent of the diet that year. Livestock accounted for approximately 2 to 4 per cent of the diet during other years.

The annual consumption of game birds and songbirds varied little from year to year, and amounted to about 3 per cent of the average diet.

Seasonal Variations in Foods

Rabbits were most important in the red fox diet during winter, and least fed upon during summer. Both occurrence and volume of rabbit in the diet remained high throughout the year (Table 4). Mice and rats were staple foods throughout the year, with greatest amounts taken during spring, and least amounts during summer. Lower consumption of mice during the summer also was reported by Scott (*op. cit*), Scott and Klimstra (*op. cit.*), and Latham (*op. cit.*).

The seasonal trend of red fox feeding upon poultry paralleled that of the coyote (Korschgen, *op. cit.*). Heaviest feeding upon poultry occurred during summer when consumption of this item was twice as great as during spring, nearly three times that of fall, and almost four times the amount taken during winter. Poultry occurred in about one of every three stomachs during summer; one in four during spring; and one in eight during fall and winter. The number of samples obtained for the summer months was small, but the data showed that the red fox was particularly damaging to poultry during that period when flocks are not confined and young chickens are on range during the day.

Seasonally, foods in the "other mammal" category were most often taken during the fall and winter. It is possible that most of these animals were killed by foxes, but a part could have been carcasses or offal from hunted or trapped animals. In contrast, carrion items were more heavily utilized

TABLE 4.—FOODS OF RED FOXES IN MISSOURI, BY SEASON

Season[1] / Number of Stomachs	PERCENTAGES BY OCCURRENCE AND VOLUME							
	Spring 52		Summer 29		Fall 86		Winter 839	
Food Group	*Occ.*	*Vol.*	*Occ.*	*Vol.*	*Occ.*	*Vol.*	*Occ.*	*Vol.*
Rabbits	33	24.8	24	10.7	36	36.5	41	38.7
Mice and rats	46	24.2	35	6.2	58	21.3	52	22.5
Poultry	25	21.0	35	45.0	13	16.3	12	11.6
Other mammals	10	4.0	14	1.4	11	8.1	10	8.2
Carrion	8	12.9	7	13.0	6	6.5	6	7.4
Livestock	8	9.8	3	0.3	6	2.0	8	5.4
Birds	17	0.6	10	1.2	13	1.1	15	3.8
Invertebrates	12	tr.	69	15.3	13	1.6	3	tr.
Undetermined animals	—	—	—	—	2	tr.	1	0.2
Fish and reptiles	2	tr.	—	—	1	tr.	1	0.1
Plant foods	21	2.7	35	6.9	40	6.6	20	2.1
Miscellaneous	—	—	—	—	2	tr.	tr.	tr.

[1] Spring: March, April, May; summer: June, July, August; fall: September, October, November; winter: December, January, February.

during summer and spring than during winter and fall.

Livestock, mostly young pigs, was most heavily utilized by red foxes in spring. Both summer and fall seasons rated low in livestock use by foxes, with an increased take evident in winter. Birds were fed upon in greatest amount during winter, when most of the birds taken were of the ground-roosting kind. Invertebrates ranked second as a fox food during the summer months, but were little used during other periods of the year. Plant foods, too, were most heavily utilized during the summer months. Heavy use continued through fall, and dropped to about one-third the amount during winter and spring.

Extent and Effect of Red Fox Predation

In this study, game species amounted to 43.7 per cent of the red fox diet, by volume. More than four-fifths of this amount consisted of rabbits. Red foxes eat less rabbit and more of other game than does the coyote (Korschgen, *op. cit.*), but rabbit accounted for the bulk of the game portion of the diet of both species. Of the red fox diet, 36.4 per cent consisted of rabbits, 2.8 per cent furbearers, 2.6 per cent squirrels, and 1.9 per cent game birds.

A 5-year average of more than 36 per cent rabbit in the diet for all seasons, some estimates, and simple arithmetic give some idea of the number of rabbits eaten per 100 foxes, as follows:

100 red foxes consume 0.9 lb. of food each per day (Bassett, 1939);
$0.9 \times 100 = 90$ lbs. of food per day for 100 foxes;
36.1 per cent of all food is cottontail;
$36.1 \times 90 = 32.49$ lbs. of rabbit per day for 100 foxes;
2 lbs. per rabbit (assumed average weight of young and old);
$32.49 \div 2 = 16.25$ rabbits eaten each day by 100 foxes;
16.25×365 days = 5,931 rabbits eaten by 100 foxes each year.

Thus, nearly 6,000 rabbits may be eaten each year by each group of 100 red foxes.

Although accurate, detailed estimates of fox densities were not available, some trappers' records in north-central Missouri attest to their great abundance after 1950. One farmer-trapper, during the fall of 1950, trapped 86 foxes from two farms totaling 640 acres, and still found considerable fox sign after the season. Another took 57 within one-half mile of his home during the fall of 1951—22 of them in one trap-set within 300 yards of the house. A third trapped 35 red foxes from a section of land during 10 days in January 1954. Takes of 30 to 40 foxes per season were common for many trappers, particularly in the northern part

of the state. Experienced field men estimated from 12 to 20 red foxes per square mile in northern Missouri in 1951. Actual count during "fox drives" ran as high as 18 foxes per section of land. Reports from field men indicated that similar populations existed in southern Missouri.

During the period of high fox populations, large numbers of rabbits were still taken by hunters. Missouri field bag-check data show a total hunter kill of 3,656,843 rabbits in 1948–49; 2,664,397 in 1949–50; 4,143,737 during 1950–51; 3,688,424 during 1951–52; 2,285,844 during 1952–53; 2,186,007 during 1953–54; 3,018,240 during 1954–55; and 3,438,732 during 1955–56 (Crawford, 1956). These figures clearly substantiate the ability of the rabbit, with high reproductive potential, to provide hunting even under heavy pressure of predation.

Foxes versus quail rate high as a controversial aspect of predation. Twenty-four occurrences of quail amounted to 1.9 per cent of the 5-years' food consumption studied. Half of the quail were in stomachs of foxes taken in December during the hunting season, and may have represented crippled or lost birds. At least one was of this kind, as bird shot was found in the stomach contents. Other occurrences of quail were as follows: seven in January; and one each in February, May, July, and October. The data show that red foxes occasionally feed upon quail, particularly during the winter,, but the common complaint that foxes are very destructive to quail nests and young is not supported by this study. Scott and Klimstra (*op. cit.*) also found little evidence of quail in the fox's diet, and no positive evidence of foxes feeding on quail eggs. The small amount of predation upon quail, as indicated, cannot be considered important, in view of the rapid turnover in the quail population. It is known that approximately 80 per cent of Missouri's quail are lost annually to all causes (Bennitt, 1951). The portion taken by red foxes represents only one of many types of losses, and probably includes many birds which succumb as a result of various other causes.

Information obtained from this study shows that a quail is eaten by a fox on the average of one day in 42; i.e., it takes 42 foxes to take a quail per day.

The extent of predation upon livestock was minor. Only young animals are subject to fox predation. Young pigs commonly are taken by foxes, as are lambs and kids on occasion. Such predation represents a real loss to the farmers concerned, but much of this loss might be prevented by good husbandry and the elimination of those individual predators that habitually prey upon young livestock.

In conclusion, the effect of red fox predation upon game during the 5 years of this study was interpreted as minor, except possibly in the case of rabbits, where predation may have had some limiting effect of short duration.

It was found that game, poultry, and livestock comprised 62.5 per cent of the red fox diet. In terms of man's interests, these data indict the red fox with destructive tendencies. However, there are shortcomings and dangers in accepting raw numerical data as being completely accurate. Some allowance must be made for foods eaten that did not represent fox predation: a portion of the rabbits from highway kills, disease, hunter crippling, and death from weather and other causes; poultry and livestock lost to other causes, discarded by man, and later fed upon by foxes; game birds lost as a result of crippling, disease, or other factors of normal attrition; and the beneficial aspect of predation upon game by eliminating the diseased, weak, and unfit. Allowances for such factors lead me to rate the red fox feeding habits as neutral, neither good nor bad.

SUMMARY

In Missouri, the food contents of 1,170 red fox stomachs were studied to learn: (a) the general feeding habits of red foxes; (b) the extent and effect of fox predation upon other managed wildlife species; and (c) the extent of predation by red foxes upon poultry and livestock. A total of 164 (14.0 per cent) of the stomachs were empty. Principal foods in the remaining 1,006 stomachs

were: hares and rabbits, 36.8; mice and rats, 22.0; poultry, 13.7; other mammals, 7.7; carrion, 7.7; livestock, 5.1; birds, 3.4; invertebrates, 0.7; and plant foods, mostly persimmon fruits, 2.7 per cent, by volume. The game portion amounted to 43.7 per cent of red fox diet. Of this total, 36.4 per cent consisted of cottontails and jack rabbits; 2.8 per cent, furbearers; 2.6 per cent, squirrels; and 1.9 per cent, game birds. It was concluded that the effect of red fox predation upon game was minor during the 5 years of this study.

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ECOLOGY OF MUSKRATS IN STRIP-MINE PONDS IN SOUTHERN ILLINOIS

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This investigation was made to determine the suitability of strip-mine ponds as habitat for the muskrat (*Ondatra zibethicus*); and to determine what, if any, changes in the biology of the muskrat were brought about in the transition from a natural habitat to an artificial one produced as a result of man's industrial activities. The ecology and biology of the muskrat were studied from November 1955 to May 1957 on a strip-mined area in southern Illinois.

Description of Study Area

This study was conducted on 1,792 acres of strip lands, located in Perry County, about 2 miles west of Pyatt, Illinois. Nine hundred and twenty acres of this tract, donated to Southern Illinois University by the Truax-Traer Coal Company, were investigated more intensively.

The study area was characterized by continuous "spoils" or ridges, resulting from stripping operations conducted from 1932 to 1950, with the exception of 1934. The ridges alternated with valleys and were parallel, averaging from 10 to 15 feet in height, and 50 feet from crest to crest, with an average slope of 45°. The spoils differed in size, form, and direction (Fig. 1), as well as the nature of the overburden (Verts, 1956:4).

There were 156 bodies of water on the study area, totaling 142 acres (7.9 per cent of the total area). Large, permanent ponds were numbered from 1 to 24, while smaller

Fig. 1. Aerial photograph of section of Pyatt strip lands in southern Illinois, showing direction and configuration of spoils, and type A (upper) and type B (lower) ponds.

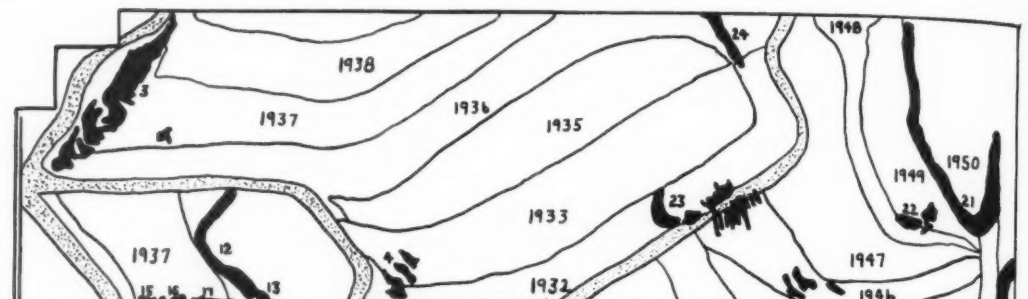

FIG. 2. Location of permanent bodies of water on the Pyatt strip lands in southern Illinois, showing dates of stripping.

ponds, both permanent and temporary, were designated as "miscellaneous" (Fig. 2).

As a result of stripping operations, ponds of two types were present. One type, designated as type A, was characterized by a highly irregular shoreline formed when low areas between the spoils filled with water from surface or subsurface drainage. Ponds classed as type B were generally long and narrow, having a shoreline that was more regular. Type B ponds increased gradually in depth throughout their length, with the lateral banks dropping off sharply; these were formed when old haulage roads leading to the coal pits were inundated.

The maximum depth of the ponds on the research area varied from 8 to nearly 40 feet. Type B ponds were either shallow or deep, depending on the depth of the coal seam. Type A ponds were generally deep in the centers, although underwater spoils transecting the ponds were sometimes present from 1 to 2 feet beneath the surface. These spoils were often exposed when the water levels were low.

The ecological variation between pond types A and B resulted from morphological differences. Type A ponds, because of the manner of formation, had more areas of shallows and places for the growth of aquatic vegetation. The bottoms of type A ponds consisted of the same materials as did the spoils forming the banks, and the absence of exposed sulfur and iron pyrites resulted in higher *p*H values. These ponds were generally alkaline.

Ponds of the B type, because of the nature of the bottom, offered little area for the growth of aquatic vegetation. Once used as haulage roads, the bottoms of these ponds were hard, and composed of slate and shale with accumulations of sulfur and iron pyrites. Upon hydrolization and oxidation, these were sources of mineral acids (Bell, 1955:85). Most of the acid ponds on the area were of this type. The banks of these ponds, except when bordered by unstripped land, were generally steeper than those of the type A ponds.

As all of the ponds on the research area received water from the same general sources, the difference in the chemistry of the water resulted from the nature of the coal overburden. Random and unequal mixing of the various strata resulted in a wide range of *p*H values for the spoils and ponds (Bell, *loc. cit.*). Hydrogen-ion concentrations for the ponds on the research area ranged from 5.0 to 7.8. In an area adjacent to the study area, Lewis and Peters (1955:121) reported *p*H values as low as 3.3 in the vicinity of heavy runoffs.

The immigration of plants into the strip-mine ponds was rapid, as the most recent ponds (6–8 years old) possessed essentially the same flora as those 20–25 years old. Studies of the aquatic plants of this and similar areas by Bell (*op. cit.*), and of the terrestrial plants by Brewer and Triner (1956), described the vegetational aspects of the area. Broad-leaved cattail (*Typha latifolia*), stonewort (*Chara* spp.), and narrow-leaved pondweed (*Potamogeton foliosus*) were the most abundant aquatics on the area. Floating aquatics were not common in the ponds, and when present were restricted to localized areas. Communities of willows (*Salix nigra* and *S. interior*) often were present along the banks, but low water levels were detrimental to these plants, in which case they were replaced by broomsedge (*Andropogon virginicus*). White sweet clover (*Melilotus alba*), goldenrod (*Solidago ulmifolia*), cheat (*Bromus secalinus*), and broomsedge were among the more abundant plants found on the banks of the ponds and on the dry spoil banks.

Narrow littoral zones and the lack of suitable areas in which to grow were the primary limiting factors influencing aquatic growth in the strip-mine ponds. Low hydrogen-ion concentrations, high salinities, instability of water levels, shale substrates, and exposed acid minerals were factors that operated on a local, rather than a general level. All of these factors influenced, and ultimately determined, the flora of the strip-mine ponds.

As most of the banks sloped sharply, the littoral zones were narrow or absent. Most of the banks that had been stripped were too rocky to provide suitable areas for plant attachment. In addition, the flocculent nature of the bottoms offered little available area for plant attachment. In the larger ponds, there was considerable wave action, which caused erosion of soils and left barren rock exposed.

DENNING

The denning habits of muskrats in the strip-mine ponds suggested their ready adaptability to environmental conditions. Although following a basic pattern, the form of the tunnels was determined by the number and position of rocks in the banks. In soft, muddy banks, the tunnels formed a labyrinth with cutoffs between tunnels and chambers. The tunnels of six dens averaged 6 inches in diameter with a flare at the entrance of 1 foot to 2 feet before connecting to an underwater slide. Generally, the tunnels sloped upward at a 45° angle from the entrance, and continued for approximately 5 feet before widening to form a chamber. Eight chambers averaged 2 feet by 3 feet by 8 inches (top to bottom). An escape tunnel, leading from the chamber into the water, was usually present.

The total length of the tunnels of the six dens averaged 18 feet, varying from 12 to 24 feet. The amount of tunneling seemed to be limited by the substrate, as the longest and most complex of the dens were in soft banks. Entrances and chambers were usually lined with sedges and several unidentified grasses. Frequently, cattail and sweet clover were pulled into the entrances, and occasionally into the chambers.

Live-trapping and information received from trappers indicated that a den with one surface and one subsurface entrance generally housed but one muskrat during the winter. Those dens with three or more entrances housed more, usually in the ratio of two entrances per inhabitant. As many as three muskrats were taken from one large den with anastomosing tunnels. Disturbance to this den, perhaps because of live-trapping, caused all three inhabitants to abandon it and establish new dens, each with two entrances. Several dens with two entrances each showed evidence of abandonment within 1 week after a muskrat was caught in the vicinity of each den.

An average drop in the water level of 2.4 feet was noted in the late summer of 1956. This drop varied from 1.5 to 3.5 feet in various ponds and caused many muskrats to leave their dens. Usually this occurred when the main entrance was exposed above the water level. Some muskrats established new dens within 1 to 2 weeks.

In addition to the dens, feeding platforms were constructed in several ponds. These generally consisted of accumulated vegetation piled on exposed rocks in the middle of a pond. The most commonly used plants here were stonewort and pondweeds.

Feeding platforms, as well as exposed rocks, logs, and stumps were utilized as latrines. Although the muskrats did not defecate in the dens proper, frequent defecation was noted on the slides leading to the dens.

POPULATIONS

Expression of muskrat populations in terms of active dens per pond and/or acre is satisfactory as a means of comparing bodies of water on the same strip-mined area. Obviously, this would be misleading if compared to density figures in terms of dens or muskrats per acre for marsh land. As marsh land presents a more continuous habitat, such expressions of density have a more realistic meaning. In strip-mine ponds, however, only a small percentage of the total aquatic acreage, that which forms a belt about the edge of the pond, is actually muskrat habitat. This is most evident especially where water depths are prohibitive to aquatic plant growth. For this reason, density has been expressed in terms of the conventional dens per acre, as well as dens per 1,000 feet of shore line (Table 1). This latter statistic is believed to convey more clearly the density of muskrats in strip-mined habitats.

To determine the annual population indexes, counts of the active dens in each pond were made in the fall before the trapping season.

In general, the amount of available food present in the different ponds could explain the different population levels, but data collected during the study were not sufficient to explain the annual fluctuations, nor the difference in population levels in seemingly similar ponds.

AGE AND SEX RATIOS

Of the 109 muskrats taken during the 1956–57 trapping season, 57 per cent were males. This percentage compares favorably with those reported by other workers: 56 per cent males in Wisconsin (Beer and Truax, 1950:324; Buss, 1941:405), 55 per cent in Ohio (Anderson, 1947:391), and 72 per cent in New York (Heit, 1949:124).

Only 43 per cent of the population sample were subadults. This is not in line with the results of others, as Gashwiler (1950:327), in Maine, reported a population of which 72 per cent were subadult, and Beer and Truax (*op. cit.*:327) in Wisconsin, reported 78 per cent. The subadult population did not have as large a percentage of males as did the adult population (51 per cent as compared to 59 per cent), but the small size of the sample was inadequate to allow any conclusions to be drawn. Anderson (*op. cit.*:394) did suggest, however, that a differential mortality factor operates in muskrat populations, causing a preponderance of males in the older age groups.

REPRODUCTION

To determine the reproductive rate of the muskrat populations on the strip lands, the uteri of females trapped in 1956–57 were examined. Each horn of the uterus was measured from the region of the cervix to the ovary, and the total number of placental scars counted.

Of 41 uteri examined, scars were present in 24. The scars of 22 uteri were legible. A total of 151 scars was counted, ranging from 3 to 15 and averaging 6.9 scars per uterus. Compared to placental-scar counts made elsewhere (compiled by Wilson, 1955:9), this figure was considerably lower. Two age classes of muskrats were found among the subadults in live- and steel-trapped animals, indicating that two litters a year were generally produced. The counts of placental scars seemed to substantiate this. An average of 6.9 placental scars per female, evenly divided into two litters, showed an average litter size of 3.4. This is lower than most counts compiled by Wilson (*ibid.*), as well as the recent work by Sather (1958:6).

The measurements of genital tracts showed that no females having a uterus of less than 60 mm. had placental scars.

TABLE 1.—AN ANALYSIS OF MUSKRAT POPULATIONS ON PYATT STRIP LANDS IN SOUTHERN ILLINOIS DURING FALL, 1954, 1955, AND 1956

Pond Number	Type	ACTIVE DENS			Acres	DENS PER ACRE			Shore Line (Feet)	Dens per 1,000 Feet Shore Line (1956)
		1954	1955	1956		1954	1955	1956		
Misc.	A	—	—	50[1]	20.2	—	—	2.5	32,020	1.6
1	B	48	19	49	10.8	4.4	1.8	4.5	10,800	4.5
19	A	4	39	47	15.6	0.3	2.5	3.0	20,280	2.4
9	A	—	—	36	3.0	—	—	9.0	4,675	7.8
3	A	—	20	30	22.3	—	0.9	1.3	18,150	1.7
21	B	45	67	28	17.8	2.5	3.8	1.6	17,800	1.6
10	B	4	5	22	6.3	0.6	0.8	3.5	5,225	4.4
8	B	1	2	17	3.7	0.3	0.5	4.6	2,270	8.5
18	A	—	—	15	4.2	—	—	3.6	6,720	2.1
14	B	—	—	15	4.4	—	—	3.4	3,575	4.3
5	A	—	—	12	2.2	—	—	5.5	3,025	4.0
12	B	—	—	8	3.3	—	—	2.4	3,160	2.7
2	A	—	3	6	1.4	—	2.1	4.2	1,650	3.8
6	B	—	6	6	7.6	—	0.8	0.8	9,900	0.6
7	A	—	—	6	1.3	—	—	4.6	2,060	3.0
13	A	—	—	6	1.4	—	—	4.3	2,340	2.6
11	A	—	3	5	1.4	—	2.1	3.6	3,025	1.7
4	A	—	—	2	0.8	—	—	2.5	1,640	1.3
Totals		102	154	360	127.7				148,315	
Averages						1.9	1.9	2.8		2.4
Type A Ponds				212	73.8	—	1.8	2.9	94,585	2.2
Type B Ponds				148	53.9	1.9	2.1	2.7	53,730	2.8

[1] Estimated.

The adversity of environmental conditions on the strip lands was apparently a detrimental factor in the number of litters produced annually, and may also have been responsible for the low average litter size. On the strip lands, conditions for muskrat populations were not ideal. Food was scarce in the winter when no green plants were available. The limited number of burrowing sites, the irregularity of the terrain, and the absence of connection to running streams to aid in movement did not provide adequate means of dispersal and caused the populations to remain more sedentary than is usual. These conditions could have limited the number of litters to two annually, with possibly three litters appearing occasionally. It might also account for the relatively low percentage of subadults in the total population.

PARASITES AND PREDATION

Cursory investigation revealed but one case of myiasis in a trapped muskrat. The advanced stage of the infection indicated that the muskrat had been parasitized *in vivo*.

Two kinds of endoparasites were found in an examination of 36 intestinal tracts. One tapeworm (*Monoecocestus* sp.) was found in the large intestine of one muskrat. Flukes (*Quinqueserialis quinqueserialis*) were present in the caecum and/or large intestine of 13 muskrats, an incidence of 36 per cent. This trematode is a common parasite of muskrats, being reported by other investigators with a greater incidence than found in this study. Meyer and Reilly (1950:469) reported an incidence of 78 per cent in Maine, Edwards (1949:547) 89 per cent in New York, and Ameel (1942:267) 80 per cent in Ohio.

The low incidence of internal parasites was probably due to the low populations of gastropods, pelecypods, and shore birds, which are necessary in the life cycle of many of the trematode parasites of the muskrat. The highly flocculent nature of the bottoms

of the strip-mine ponds was not suitable for benthic organisms, as siltation adversely affects the proper functioning of the gills.

The incidence of parasitism did not seem to be correlated with the age or *p*H of the ponds, nor was overcrowding deemed a factor. There was no appreciable difference in the incidence of parasitism observed in different age or sex groups; however, the small number of specimens involved was not conclusive.

Only one incident of predation was discovered and bore inconclusive evidence of work by mink (*Mustela vison*). Examination of several mink scats revealed no remains of muskrats. Mink were not common on the research area, and probably did not greatly affect the muskrat population.

FOOD HABITS

Field Observations

The food habits of muskrats inhabiting the strip-mine ponds were determined by weekly or monthly observations of the cuttings of food plants littering the banks of ponds. Several difficulties were involved in an analysis of food habits by this method. Cuttings observed did not yield accurate information as to the volume or weight of plant material ingested. For example, each cattail and sweet clover plant cut was recorded as one cutting, although the amount of food actually obtained was different. As only plants along the banks of the ponds were observed as cuttings, several items that grew on the sides of the spoils and occasionally taken by muskrats may have been overlooked.

In the summer, when foods were readily available in all ponds studied, a wide diversity of items was taken. In ponds that contained cattail, this item formed about 50 per cent of the diet. Sweet clover, soft stems and leaves of young broomsedge and goldenrod, and willow made up approximately equal amounts in the diet. Where cattail was absent, sweet clover constituted 40 per cent of the diet, with broomsedge, goldenrod, and willow each making up about 10 per cent. Local peculiarities of the flora were noticeable in the diet of muskrats on the strip lands. In localized areas where soft-stem bulrush (*Scirpus validus*) and eelgrass (*Vallisneria americana*) grew profusely, these items were often found to constitute as much as 50 per cent of the muskrats' diet.

Cuttings that were observed one or more times and believed to have been included in the summer diet were: spike rush (*Eleocharis obtusa*), soft-rush (*Juncus effusus*), pondweeds, sedges (*Cyperus ferrugines-cens*), manna grass (*Glyceria* sp.), nightshade (*Solanum* sp.), rose (*Rosa* sp.) and corn (*Zea mays*). The one instance in which corn was found occurred near a highway, where the ears probably had fallen from a passing vehicle.

The winter diet was less diversified than the summer diet, as less variety was available. Field observations revealed about 75 per cent cattail in the diet, predominantly rootstocks, and small amounts of sweet clover and willow. Digging in the banks for roots of grasses, willows, and clover was noted as being common at this time of the year.

When the ponds became frozen, feeding probably was concentrated on submerged aquatics and roots that could be dug from the banks. No evidence of storage of food was noted at this time of the year.

There were no noticeable peculiarities in the diet of muskrats in the fall and spring. Rather, a transitional change in the diet was noted from the summer to winter, and from winter to summer which was largely dependent upon the availability of plants as they sprouted in the spring or dried up in the fall.

Stomach Analysis

The stomach contents of 60 muskrats collected on the research area in early December 1956 were analyzed. These stomachs were preserved in 10 per cent Formalin, and the contents later washed and examined under a binocular dissecting microscope. Prior to analysis, a reference collection of plants known to be utilized for food was made, and slides were prepared of vascular and epidermal tissues.

TABLE 2.—FOOD ITEMS RECORDED IN 60 STOMACHS OF MUSKRATS TAKEN FROM PYATT STRIP LANDS IN SOUTHERN ILLINOIS, DECEMBER 1956

Food Item	Per Cent Volume	Per Cent Frequency of Occurrence	Range, Per Cent of Volume per Stomach
Cattail (*Typha latifolia*)	15.7	82	5–100
Pondweed (*Potamogeton foliosus*)	10.4	53	trace–75
Stonewort (*Chara* sp.)	5.3	20	trace–100
Willow (*Salix interior*)	3.8	25	trace–40
Sweet clover (*Melilotus alba*)	1.3	12	5–20
Broomsedge (*Andropogon virginicus*)	0.9	12	trace–20
Pondweeds (*Potamogeton* spp.)	0.4	8	trace–10
Green algae (*Oedogonium* sp.)	0.4	3	trace–25
Blue-green algae (Cyanophyta)	0.3	3	trace–15
Wild lettuce (*Lactuca scariola*)	0.2	5	trace–10
Unidentifiable	61.3	–	–

Volume was determined by estimating the percentage of the total that was represented by each food item in the stomach sample as seen in the field of the microscope. Frequency of occurrence was determined by calculating the percentage of stomachs in which each food item was found.

Of the stomach contents examined, 61.3 per cent were unidentifiable (Table 2). In concurrence with field observations, cattail was most frequently taken and occurred in the largest quantities. Narrow-leaved pondweed and stonewort were shown by the stomach examinations to be important items in the winter diet, although on the basis of field examinations not considered as significant. Because these plants were submerged aquatics, their selection as food was not observed as easily as the cuttings of cattails or willows. Pondweeds and stonewort had been observed as padding materials for dens and feeding platforms but, prior to stomach examination, were not considered important food items.

The appearance of green and blue-green algae in several stomachs seemingly indicated incidental items that were ingested while feeding. Similarly, the muskrat hair found in 10 (17 per cent) of the stomachs probably was accumulated while the animals groomed themselves.

Although the sample size was too small to give conclusive evidence, there seemingly was no significant difference in the dietary patterns exhibited by muskrats of different ages or sexes.

Availability and Preference

Much of the diet of muskrats in strip-mine ponds was determined by availability. In the absence of such foods as cattail and sweet clover, coarse plants sufficed. As an opportunist, the muskrat accepted a wide range of plants as food, and the adaptation to eating broomsedge and goldenrod on the strip lands was probably caused by availability. Also, the low utilization in winter of such items as broomsedge, goldenrod, and sweet clover, which ranked high in the summer diet, obviously was due to the scarcity of these plants in December when the muskrats were taken. The lack of such soft, green plants perhaps forced the muskrats to select items that would otherwise be disregarded.

Preference in the selection of certain items was demonstrated by the action of muskrats in certain ponds not too distant from stands of cattails and round-stem bulrushes. Here, the muskrats traveled nightly to feed upon these preferred plants, even though there was an abundance of broomsedge, goldenrod, and sweet clover in the ponds in which the dens were located.

Shoots of young plants were taken in preference to roots when available, although in the winter months and especially when the ponds were icebound, roots were unearthed frequently.

TRAPPING

During the trapping season 1956–57 (December 1 to January 15), 105 muskrats were

taken from the strip-lands research area. This represented approximately 30 per cent of the estimated fall population. Although trapping was primarily for muskrats, an incidental catch of 25 raccoons (*Procyon lotor*) and several opossums (*Didelphis marsupialis*) was also reported by the local trappers.

At no time were there more than 100 traps on the area. In all, 1,260 trap-nights were recorded during the trapping season. Although some trappers were in the practice of "pulling" one or more unproductive traps without reporting this, the total figure was believed to be reasonably accurate.

An average of 0,08 muskrat per trap-night was recorded, ranging from 0.01 to 0.29 in various ponds. Of the 1,260 trap-nights, 53 per cent were recorded the first week of the trapping season and 36 per cent the second. Of all the animals harvested, 69 per cent were taken the first week, and 18 per cent the second. This compares favorably with the trapping pressure each week, the two factors being interdependent. No muskrats, except two taken by the investigator, were trapped on the area after December 15.

Trapping pressure on the 17 ponds used by trappers was determined first by accessibility, next by muskrat populations as determined by feeding sign, and last by ease of trapping. Ponds nearest the roads were the first to be trapped, and from the standpoint of total catch, were the most productive. As the banks of most of the ponds had a slope of approximately 45°, considerable difficulty was encountered in setting and running trap lines.

Although the trapping season in Illinois was open for 45 days, active trapping was recorded on the research area for only 15 days. Trappers remained only as long as the catch was high. When a decline ensued, the traps were removed from the strip lands and reset in the neighboring streams and sloughs. In the middle of December, heavy rains and freezing temperatures gave impetus to this relocation of traps.

Only 50 per cent of the pelts taken from the research area were considered to be in a prime condition. As these were caught within a 2-week period, perhaps no appreciable difference between the first and last pelts taken could be expected. Examination of other pelts taken in the general vicinity showed that the largest number of prime pelts was taken near the end of the trapping season.

EXPERIMENTAL PLANTINGS

Experimental plantings were made in the spring and summer of 1956 to determine the suitability of the Pyatt strip-mine ponds for additional forms of aquatic vegetation, and to provide additional food for muskrats and waterfowl. The species planted were selected on the basis of their importance as muskrat foods (Bellrose, 1950:314). Each was planted in ponds offering the best environmental conditions for the species, as indicated by McAtee (1939) and Martin and Uhler (1939).

Stock was obtained from commercial nurseries and was planted by hand (Table 3). Seeds were broadcast; rootstocks, tubers, and bulbs were planted at approximately 1-foot intervals in water from 1 to 3 feet deep. Plantings in type A ponds were made between the finger-like projections of land, and wherever shallows were large enough to accommodate them. Type B ponds offered good depths for planting at the shallow ends, but this was offset by the hard, slag bottoms.

Plantings were checked in late August 1956, and failures correlated with ecological conditions in the ponds. In determining the percentage of successful plantings, individual plants were counted whenever possi-

TABLE 3.—QUANTITY OF MATERIAL UTILIZED IN EXPERIMENTAL PLANTINGS IN STRIP-MINE PONDS IN SOUTHERN ILLINOIS IN SPRING, 1956

Species	Quantity
Pondeteria cordata	280 plants
Zizania aquatica	1 bushel of seeds
Nelumbo lutea	500 seeds
Sagittaria latifolia	1000 plants
Sagittaria rigida	1050 plants
Polygonum muhlenbergii	450 plants
Castalia tuberosa	750 plants
Phragmites communis	1000 plants
Scirpus acutus	1300 plants

ble. In dense areas of successful growth, samples were taken in a representative section of the plant community, and comprised a fraction (one-tenth to one-fifth) of the total area of the community.

Two forms were planted from seed, neither growing to maturity. Wild rice (*Zizania aquatica*) germinated well, as compared to laboratory germination of 100 seeds from the same stock (20 per cent in the field to 30 per cent in the laboratory). Wild rice seedlings were either unable to secure attachment (in a type B pond) and drifted to the banks and died, or they secured attachment and died before reaching a height of over 12 inches (in a type A pond). Scarified seeds of American lotus (*Nelumbo lutea*) germinated poorly in a type B pond. Less than 1 per cent germination was obtained in the field, whereas 97 per cent of 100 seeds from the same stock germinated in laboratory experiments utilizing water from the same pond. Seemingly the cause of the failure was the composition of the pond bottom. Seedlings of American lotus reached a leaf diameter of 3 inches and then died.

Arrowhead (*Sagittaria latifolia*) was the only plant to bloom and set seed; success of 43 per cent was obtained. Hard-stem bulrush (*Scirpus acutus*) demonstrated a success of 15 per cent, and tuberous water-lily (*Nymphaea tuberosa*), 16 per cent. Both water-lily and bulrush, although not setting seed, did establish extensive root systems. All plants that did successfully grow showed some utilization by muskrats, without which the total success may have been greater.

Pickerelweed (*Pondeteria cordata*), deep water duck potato (*Sagittaria rigida*), marsh smartweed (*Polygonum coccineum*), and reed (*Phragmites communis*) demonstrated no ability to grow in the ponds in which they were planted.

The failure of these plantings was attributed to one or a combination of as many as four probable factors: 1) failure to secure attachment owing to the presence of rock and flocculent bottom materials; 2) presence of excessive minerals in the bottoms and water of several ponds; 3) drop in water level; and 4) competition with native forms.

RECOMMENDATIONS

On the basis of the findings of this study, certain recommendations for the management of muskrats in strip-mine ponds may be made. Leveling of the banks, elimination of rock, use of economical water-level control devices, and the development of greater areas of shallows will facilitate the growth of aquatic vegetation in strip-mine ponds. Planting of aquatic plants proven to be acclimated to existence in strip-mine ponds will increase the amount of food available to muskrats.

A greater harvest from the more heavily populated ponds could be realized, and may aid in raising the reproductive rates of the muskrats in the strip-mine ponds. Utilization of the populations existing in the smaller ponds would increase the total harvest from the strip lands, and would probably aid the populations themselves by removing a larger percentage of the older muskrats.

It is necessary, however, that any successful management practices be of economic feasibility. As the annual harvest is low, I feel that, with the exception of increasing trapping pressure, no concerted efforts to manage the muskrat populations in such areas should be attempted.

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SUMMARY

A study of the ecology of the muskrat in strip-mine ponds in southern Illinois was part of a program to determine the wildlife potential of such lands. A total of 360 dens was recorded on some 142 acres of strip lands. The density ranged from 0.3 to 9.0 dens per acre, averaging 2.8. This constituted 2.4 dens per 1,000 feet of shore line. Males constituted 57 per cent of the population. Subadults comprised 43 per cent of the animals. Observations indicated that reproduction was low, with but two litters produced annually, averaging 3.4 kits.

Only two types of internal parasites were found, with low rates of incidence recorded, probably owing to the lack of intermediate hosts.

Field observations indicated that cattail, sweet clover, broomsedge, and goldenrod formed a substantial part of the summer diet, whereas the winter diet was composed largely of cattail rootstocks and willows. Stomach analysis indicated that stonewort and pondweeds also make up a large part of the winter diet. Both availability and preference are important in the selection of food items by muskrats.

Movement was greatest in February at spring dispersal, and in late summer when low water levels caused the abandonment of dens.

Experimental plantings of arrowhead, water-lily, and bulrush were successful in the strip-mine ponds, although several other muskrat food plants did not become established owing to the adverse ecological conditions.

Intensive management for muskrats on the strip lands studied is not recommended because of economic infeasibility, but incidental management could be practiced secondarily to other management procedures.

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HIGHWAY MORTALITY AS AN INDEX OF DEER-POPULATION CHANGE

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This paper explores the value of records of deer killed accidentally by motor vehicles on Wisconsin highways, and it discusses the potential value of the records in the form in which they are now available. The deer that die accidentally on highways are referred to in this report as road-kills. One of the basic questions explored here is whether or not the reported number of road-kills can be used as an annual population index. In addition to evaluating yearly trends, the sex and age composition of the dead animals is discussed.

I found no published reports to indicate that data on deer road-kills have been fully evaluated to determine whether or not the samples secured would reflect population trends and the sex and age composition of the herd. However, a verbal report on the subject was presented at the Midwest Wildlife Conference in 1951 by Merrill Gilfillan of Ohio. This report stimulated some of the thoughts that are expressed in the present paper.

FIG. 1. Major habitat types of deer range in Wisconsin: (1) forest-swamp region, (2) intermediate zone of forests and farms, (3) highly developed agricultural and industrial area (after Dahlberg and Guettinger, 1956:32).

MATERIALS AND METHODS

In Wisconsin, the white-tailed deer (*Odocoileus virginianus*) utilizes a wide variety of habitat types (Fig. 1). For administrative purposes of the Wisconsin Conservation Department, the state is divided into five game-management areas, each composed of a group of counties (Fig. 2). In this paper, these five areas are the smallest units used in presenting data.

Method of Reporting Deer

Conservation wardens complete and file a formal seizure card on each deer that is reported killed illegally and is field checked by a department employee. Space is provided on the card for recording, among other things, the warden's name, date and location of the dead deer, cause of death, sex and

[1] I wish to thank the following persons of the Wisconsin Conservation Department for the part that each played in making it possible to assemble this report: G. S. Hadland and J. R. Smith for facilitating my use of official deer-mortality records; O. G. Grant and W. J. Zelinske for assistance in handling the individual reports; O. S. Bersing for furnishing department reports and advice on deer; game and law-enforcement division fieldmen for relating experiences with road-killed deer; and Cyril Kabat for encouragement and counsel in all phases of the study. Credit is extended to Mrs. T. C. Radke, G. D. Jones, and H. F. Jahn for helping to complete the tedious work on the many tabulations used in the report; D. R. Thompson and J. H. Torrie for statistical counsel; W. D. Ryan and R. T. Hubbard of the Wisconsin Highway Planning Survey for supplying and explaining in detail the information relating to Wisconsin highways and traffic; R. L. Hine for editorial assistance; J. J. Hickey, R. A. McCabe, J. B. Hale, and R. A. Hunt for critical advice; and B. J. Sohre for typing the manuscript.

FIG. 2. Area organization of Game Management Division, Wisconsin Conservation Department.

age, and disposition of the carcass. Seizure cards are made out for both salvageable and nonsalvageable deer. Nonsalvageable animals are usually disposed of in the vicinity of the accident. A file of the completed seizure cards for more than 10 years is available in the Madison office of the Wisconsin Conservation Department. The records containing road-killed deer in this file form the basis for this study.

Variation in Reporting Deer

Although the system for reporting road-kills was standardized, comments by fieldmen indicated that not all road-killed deer were recorded during the 10-year period considered. Determination of the portion of road-kills reported annually is not possible with the data available. Therefore, the analysis of deer road-kills presented here is based only on that portion of the mortalities reported, not on all road-kills.

Examination of the percentage of nonsalvageable deer reported yearly helps one to determine if the number of road-kills reported was biased between years (Table 1). The increase in percentage of nonsalvageable carcasses in 1954 and 1955 can be explained by an increase in the efficiency of reporting road-kills, since there is no apparent reason to suspect that the accidents in 1954 and 1955 were any more severe than those occurring in previous years. Deer-crossing signs to warn motorists of regularly used deer trails are located throughout the state. In 1955 the percentage of nonsalvageable deer in northern (northwest, northeast, and west-central of Fig. 2) forested parts of Wisconsin averaged 67 per cent and in southern agricultural Wisconsin averaged 43 per cent. The size of the samples involved precludes the possibility that this difference is due to chance alone. Any one of four phenomena operating singly or in combination could explain this situation: (1) The speed of motor vehicles at the time of accidents was greater in the forested region than it was in the agricultural region; (2) field personnel in the two regions employed different criteria for classifying deer carcasses as nonsalvageable; (3) motorists illegally removed a larger portion of salvageable deer in forested Wisconsin than they did in agricultural Wisconsin; and (4) deer from forested areas were in poorer physical (nonsalvageable) condition than deer from agricultural areas. None of these four possible explanations could be explored with the data available. For the purpose of this report, deer-population trends will be reviewed only on the basis of the annual road-kill reports from 1946 through 1953. In other

TABLE 1.—PERCENTAGE NONSALVAGEABLE ROAD-KILLED DEER IN WISCONSIN[1]

Year	Total Road-kills	NONSALVAGEABLE	
		No.	Per Cent
1946	360	93	26
1947	382	119	31
1948	543	179	33
1949	526	205	39
1950	498	168	34
1951	424	143	34
1952	440	139	32
1953	728	265	36
1954	1,072	543	51
1955	1,443	822	57
Totals and mean	6,416	2,676	41.7

[1] Some totals in this table are less than those given in Table 2 because not all deer were classified as salvageable or nonsalvageable.

years, when reporting efficiency varied, error could occur if available road-kill figures were used to reflect population changes.

Method of Computing Total Vehicle Miles

A general increase in motor-vehicle travel occurred in 1946–55 and constitutes a source of potential bias in this study. Records of annual vehicle miles of traffic pressure on Wisconsin highways are available in annual reports issued by the State Highway Commission (see Wis. Highway Comm., 1949 *et seq.*). The term "vehicle mile" is defined by the Commission as one motor vehicle traveling one mile.

The program of making state-wide traffic-volume counts was inaugurated in 1948 as a part of the continuing traffic survey conducted by the Wisconsin Highway Commission. At that time the state was divided into nine areas or units, one traffic checker was assigned to each unit, and counts were taken each year in each county of the state. In 1953, the state was redivided into ten areas and the program curtailed to the extent that five traffic checkers covered approximately five areas or about one-half of the state each year. The areas studied consisted of blocks of counties well distributed over the entire state.

Although the total area sampled each year changed slightly between 1948 and 1954, the Commission's method of determining the volume of traffic remained essentially the same. Portable mechanical counters were used by the traffic checkers on either end of designated lengths of "state trunk" (state and federal) and county highways to determine the number of vehicles passing over these sections of highway in 24-hour periods. Repeat counts of the same length of highway in different months provided measurements of seasonal differences in the volume of traffic. From all counts made on each particular section of highway, the annual 24-hour average number of vehicles was calculated. This figure, multiplied by the length of the road segment, provided a value referred to in this paper as the annual 24-hour average vehicle miles.

Vehicle miles of travel were computed for every measured section of rural highway. The total figures were combined to provide a county total of vehicle miles for each type of rural highway (i.e., state trunk, county, and town). The annual 24-hour average number of vehicle miles was multiplied by 365 or 366 to provide an annual estimate of the total volume of traffic in each of the 71 counties. Summation of the county estimates provided a single value of traffic pressure for the state. The Highway Commission considers these figures reliable estimates since they represent the cumulation of vehicle miles on many individual sections of highway; the estimates were not, however, based on samples randomly selected by means of a statistical design.

Traffic counts were not made in every county in 1953 and 1954. In these years, the annual 24-hour average of vehicle miles in certain counties was estimated from the previous year's figures corrected by percentage changes in traffic counts made in neighboring counties. Examination of data collected in every county between 1948 and 1952 indicated that this procedure could be used reliably.

Game and law-enforcement personnel of the Wisconsin Conservation Department informed me that very few deer (probably less than five per cent of those road-killed) meet death accidentally by motor vehicles on town roads and trails in Wisconsin. Only 8 to 12 per cent of all vehicle miles in the state are annually reported as occurring on town roads and trails. Since the bulk of the deer are accidentally killed on state trunk and county highways, only the vehicle miles from these types of roads are used in this report.

Measured average speeds of all types of vehicles on state trunk highways ranged from 47.8 miles per hour in May of 1946 to 54.5 in May of 1955 (Wisconsin Highway Commission, 1955). I found no specific method to evaluate the influence that increasing average speeds of motor vehicles may have on the number of deer that are road-killed.

Assumptions

Certain assumptions were made by me concerning the vehicle miles used in this report: (1) that the variation in average speed of motor vehicles on Wisconsin highways between 1946 and 1955 did not materially affect the numbers of deer accidentally killed in different years; and (2) that the 10,041 miles of state trunk and county highways in Wisconsin constitute transects that are well distributed throughout the deer range, except in the winter yarding areas. The pattern of daily movements of deer is assumed to vary to an unknown degree between years due to climatic conditions that modify the daily cruising radius of deer, especially in the

TABLE 2.—REPORTED NUMBERS OF DEER ROAD-KILLED IN WISCONSIN[1]

Game Area	1946[2]	1947[2]	1948[2]	1949[2]	1950[2]	1951[3]	1952[3]	1953[3]	1954[3]	1955[3]	Ten-year Total
Northwest	88	109	105	92	100	69	59	99	132	157	1,010
Northeast	136	126	173	175	147	100	86	206	295	391	1,835
West central	85	102	180	180	145	148	186	259	322	411	2,018
East central	22	25	47	48	77	88	100	164	247	357	1,175
Southern	29	24	38	31	33	43	34	62	97	156	547
State-wide	360	386	543	526	502	448	465	790	1,093	1,472	6,585

[1] Figures in this table are grand totals; all other tables may show fewer deer.
[2] Data compiled by the author.
[3] Data compiled by O. G. Grant.

northern yarding areas where the depth of snow varies between winters. This factor is not considered to be a major variable affecting this study.

DEER MORTALITY ON HIGHWAYS

Number of Deer Accidentally Killed

The numbers of deer reported as road-killed in the five game-management areas (Fig. 2) totaled 6,585 in the period 1946–55 (Table 2). At least one deer was reported accidentally killed in each of Wisconsin's 71 counties in 1955. This 10-year accidental deer kill must be considered a known minimum, since one can assume that some deer struck by motor vehicles escape and die without being found and some are found but are not reported. Between 1946 and 1955, an estimated 714,333 deer were harvested by gun and 4,380 by bow and arrow (calculated from Dahlberg and Guettinger, 1956; Bersing, 1956; and Bersing and Hale, 1956). As a mortality factor operating on the population, the accidental highway loss of deer is apparently much more important than the legal bow and arrow harvest, but is very small compared to the legal gun harvest.

To determine whether or not road-kills reflect trends in the size of the deer herd, trends in the road-kill are compared (below) with two population indices, namely hunting-season and sight records. A further test is to determine if the indicated population changes calculated from road-kills are biologically possible.

Hunting-season records.—During the 10-year period starting with 1946, three forked-horn buck seasons were followed by a combination antlerless and forked-horn (not over 2 inches) buck season in 1949, two any-deer seasons, and four forked-horn buck seasons (Fig. 3). Leopold (1933:42) demonstrated with theoretical but realistic examples that, if deer survive other mortality factors, a population will increase greatly under only buck hunting. Increases in the deer population are suggested by the curve of the Wisconsin deer road-kill during years when buck seasons were held. Under more liberal hunting seasons, the accidental deer kill decreased gradually with the addition of each liberal hunting season and reached a low point in 1951, the last year an any-deer season was held.

Data from the state of Delaware indicate the same relationship between legal and accidental deer kills (McGinnes, 1955).

This demonstration of a general and inverse relationship existing between legal gun-kills and road-kills suggests that general trends in the size of the deer herd are reflected by the figures on road-kills.

Sight records.—Starting in 1950, for the two northern game areas (Fig. 2), records are available on the number of deer reported seen by hunters while they were gun-hunting. These sight records follow the general trend of road-kill figures corrected for annual differences in vehicle miles, but the correlation coefficient (0.630) is less than the value (0.950) listed by Snedecor (1937) at the 0.05 level of significance. Lack of a significant correlation could be due to variations in the sight records. Numbers of deer observed are unquestionably influenced by

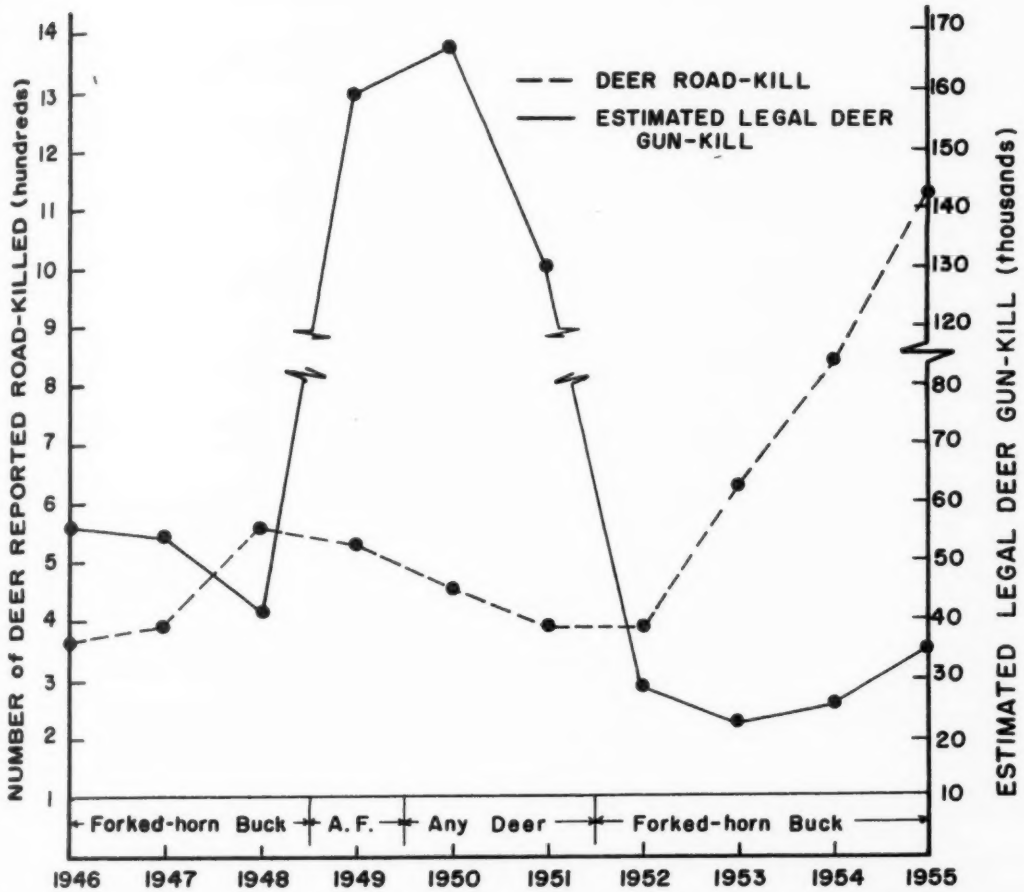

FIG. 3. Trends in the annual deer road-kill and the estimated legal deer gun-kill under different types of hunting seasons, 1946–55. (The estimated legal gun-kill [from Bersing, 1956; Bersing and Hale, 1956] was calculated from deer-hunter questionnaires in all years except 1953, 1954, and 1955; values for these years are the number of deer registered at checking stations. *A.F.* in 1949 refers to antlerless deer plus forked-horns not over 2 inches in length. Road-kill figures for 1946 and 1947 are uncorrected for variations in vehicle miles.)

the number of hunters afield and the presence or absence of snow on the ground at the time observations are made. I conclude that additional data from more years are needed to reach a final conclusion regarding the specific relationships between road-kill and hunting-season sight records of deer.

Indicated population changes.—If the annual changes in the road-kill reflect deer population trends, the percentage changes must be biologically possible in terms of deer reproduction and mortality.

Deer are usually considered to be capable of an increase in total numbers of 30 per cent each year under satisfactory range conditions (Dahlberg and Guettinger, *op. cit.*:124). O'Roke and Hamerstrom (1948), who found an average annual increase of about 44 per cent, calculated an increase of 60 per cent for 1 year in a deer herd subjected to an any-sex harvest.

All of the percentage changes in road-kills presented in Table 3 fall within the realm of biological possibilities, except for 1 year, 1953. There was no evidence in Table 1 to suggest that the percentage of nonsalvageable deer in 1953 differed from that of other years. Association between sight-

TABLE 3.—ANNUAL CHANGES IN REPORTED DEER ROAD-KILL IN WISCONSIN

Game Area	Corrected Highway Deer Road-kill[1]						Indicated Percentage Change between Years				
	1948	1949	1950	1951	1952	1953	1949	1950	1951	1952	1953
Northwest	104	93	95	63	51	80	−11	+2	−34	−19	+61
Northeast	164	168	133	87	75	175	+2	−21	−35	−14	+133
West central	214	204	153	145	173	223	−5	−25	−5	+19	+29
East central	35	35	56	61	67	102	0	+60	+9	+10	+52
Southern	34	27	27	32	24	41	+21	0	+19	−25	+71
State-wide	551	527	464	388	390	621	−5	−14	−20	+1	+60

[1] (Expressed per stated vehicle miles each year; 500,000,000 used for the northwest and northeast, 1,000,000,000 used for the west-central and east-central, and 1,500,000,000 used for the southern game area. Corrections are based on variations in traffic pressure in each game area and the entire state.) Traffic-pressure records taken from Wisconsin Highway Commission (1949, 1950, 1951, 1952, 1953, 1954).

record and road-kill indices was close, except in 1953 (Fig. 4). Greater care was apparently taken in reporting both salvageable and nonsalvageable deer starting in 1953.

Sex and Age Ratios

Fieldmen of the state's Conservation Department reported the sex and age of 5,981 deer road-killed in Wisconsin from 1946 through 1955. Yearling and older deer were not differentiated when reported. Hence in the following summary, the deer are classified as "adult" and fawn, and as male and female. Although the deer are classified according to this scheme in all months of the year, during certain periods the validity of the classification may be questioned, since the deer were placed in the categories largely on the basis of gross external characteristics. Confusion could most easily arise over the size of animals. For example, large doe fawns could be classified as adults. For this reason, I did not analyze sex and age ratios in detail for all months.

Sex ratios of fawns.—Robinette, Gashwiler, Low, and Jones (1957) advanced some interesting hypotheses regarding differential survival between sexes of mule and black-tailed deer (*O. hemionus* ssp.) fawns. Disproportionate losses between sexes were related to range conditions and the severity of the winter preceding birth. The limited sizes and restricted distribution of samples prohibit analyzing the Wisconsin data along similar lines.

The yearly sex ratios of 1,574 road-killed fawns (Table 4) and average seasonal sex ratios (Table 5) do not differ significantly from the national average of 51.5:48.5 for fawns 5 to 7 months of age reported by

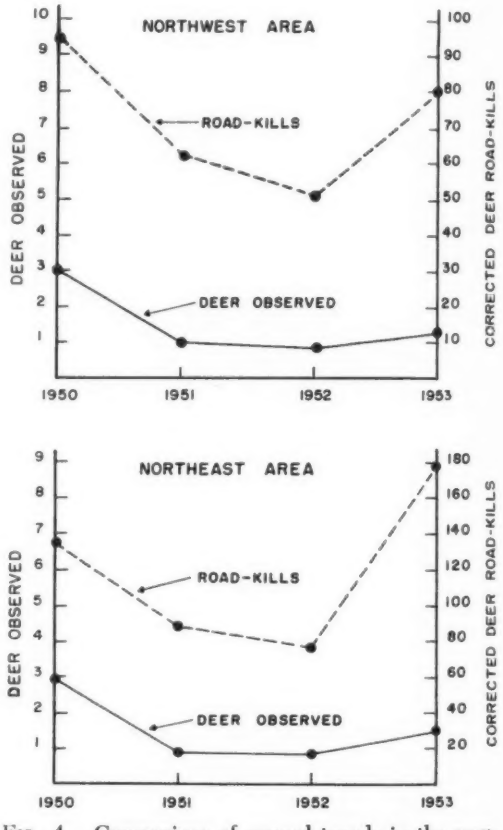

FIG. 4. Comparison of annual trends in the number of deer road-killed per 500,000,000 vehicle miles and the number of deer observed per 10 hours during the fall gun-hunting season. Sight records are based on data compiled by the Wisconsin Conservation Department (1950, 1951, 1952, 1953).

TABLE 4.—YEARLY SEX RATIOS OF FAWNS ROAD-KILLED IN WISCONSIN

	1946	1947	1948	1949	1950	1951	1952	1953	1954	1955	Total
Number of deer	96	104	151	134	120	88	81	198	254	348	1,574
Per cent male[1]	59	50	47	51	45	43	46	54	47	47	48.7
Males:100 females	146	100	89	105	82	76	84	115	90	87	95

[1] Chi-square tests indicate no significant difference of any annual value from the expected national average of 51.5 per cent male for fawns between 5 and 7 months of age (Severinghaus and Cheatum, 1956:66); the 10-year total is significantly lower than the national average.

Severinghaus and Cheatum (1956:66). The percentage of males in the 10-year total sex ratio for road-killed fawns (Table 4) is significantly lower than the national average.

While sample-size limits complete evaluation of fawn sex ratios for individual years, the 10-year total suggests that male fawns may be less vulnerable than female fawns to accidents with motor vehicles. Of 2,400 fawns shot by hunters in November during Wisconsin's three liberal gun-hunting deer seasons (1949, 1950, 1951), 53 per cent were male fawns (Table 6). Thus, male fawns occur in this population in expected proportions. Possibly the larger size of male fawns (Severinghaus and Cheatum, *ibid.*: 76) provides them with added physical stamina that helps them avoid accidents with motor vehicles.

Sex ratios of adults.—Of 4,407 adult deer (yearlings or older) road-killed, 45.0 per cent were males (Tables 7 and 8). To evaluate these data further, it is necessary to determine whether or not the sex ratio was affected by the different types of gun-hunting seasons. Statistical tests for individual years (Table 7) gave no indication that the sex ratio of road-kills following liberal seasons appreciably differed from that following buck seasons. This suggests that in buck seasons the illegal kill of adult does in Wisconsin was of sizable proportions during this period. If this were not true, the proportion of bucks in the road-kill in years following any-deer hunting seasons would be greater. DeBoer (1957) reported an illegal kill of eight does for every ten bucks harvested in a buck-hunting season on 7,684 acres in one forested central Wisconsin county. These data conform with the road-kill figures that suggest a high illegal loss of adult does during buck-hunting seasons in Wisconsin.

Since adult sex ratios were similar between years, I combined data for the 10-year study period and computed average monthly sex ratios (Table 8). Seven months differed significantly from the mean for the calendar year. On the average, the number of males reported road-killed in fall (October and November) is slightly more than two times the number dying in the other 10 months of the year. It is during October and November that at least 75 per cent of the deer breed in Wisconsin (Dahlberg and Guettinger, *op. cit.*:44).

Figures on the fall sex ratio of adult deer are available from Wisconsin hunting seasons and from prehunting shining tallies (Table 9). The percentage of males derived from road-killed deer is significantly greater than the values from prehunting shining tallies and from adult deer taken

TABLE 5.—AVERAGE SEASONAL SEX RATIOS OF FAWNS ROAD-KILLED IN WISCONSIN, 1946–55

Season	No. of Fawns	Per Cent Males[1]	Males Per 100 Females
Summer (June–Sept.)	388	47	89
Fall (Oct.–Nov.)	752	50	100
Winter (Dec.–Mar.)	345	48	93
Spring (Apr.–May)	89	51	104

[1] Chi-square tests indicate no significant difference of any value from the expected national average of 51.5 per cent male for fawns between 5 and 7 months of age (Severinghaus and Cheatum, 1956:66).

TABLE 6.—FALL SEX RATIOS OF FAWNS IN WISCONSIN

	Road-kill	Gun Hunting[1]	Bow Hunting[1]
Years involved	1946–55	1949–51	1948–54
Number of fawns	752	2,400	896
Per cent male	50	53	56[2]
Males:100 females	100	112	127

[1] Data from Dahlberg and Guettinger (1956).

[2] Chi-square tests indicate a highly significant difference of value from the expected national average of 51.5 per cent male for fawns between 5 and 7 months of age (Severinghaus and Cheatum, 1956:66).

TABLE 7.—ANNUAL ADULT SEX RATIOS OF WISCONSIN ROAD-KILLED DEER, 1946–55

Year	Number of Deer	Per Cent Male[1]
1946	237	44
1947	239	39
1948	340	40
1949	353	45
1950	338	46
1951	313	50
1952	320	48
1953	471	49
1954	764	46
1955	1,032	42.6
Total and mean	4,407	45.0

[1] Chi-square tests indicate no significant difference between any one year and the 10-year average of 45.0 per cent.

by hunters. Evidently, during the rut (chiefly October and November) adult bucks move about more than do other deer, cross the highways more times than other deer do, and meet death more frequently than do adult does, even though does make up a larger percentage of the herd than do bucks (Dahlberg and Guettinger, *op. cit.*:93).

Because adult bucks are more vulnerable to highway accidents in October and November than is any other sex or age group, data from these two months are omitted, and monthly comparisons are more pertinent on the basis of the 10-month average percentage (38.1) of males (Table 8). In March and April, the percentage of adult bucks was significantly lower than that for the 10-month average, and in June it was significantly higher. I believe that the low proportion of bucks in the road-kill in March and April results from increased vulnerability of the female, at least in large part. Adult does disperse from winter yards early in spring and prepare to drop their fawns. During the late stages of pregnancy, there undoubtedly is an above-normal consumption of succulent green forage, such as Leopold, Riney, McCain, and Tevis (1951) reported for the California mule deer (*O. h. californicus*). New grassy vegetation is essential for milk production and is rich in vitamin K, a blood-coagulating factor, which would be very important to the doe at the time fawns are born, largely in May and June in this state. Preferred food is frequently available first on open road cuts, bringing the deer in close proximity to moving vehicles.

The higher than average percentage of adult male deer road-killed in June is undoubtedly explained by a reduction of daily movements by adult females. Most fawns are born in Wisconsin in May and June (Dahlberg and Guettinger, *op. cit.*:45). Therefore, in June some breeding does are with their fawns that were born in May and others are preparing for birth and are giving birth to fawns in secluded areas in June. These breeding activities are known to restrict the daily movements of does (Severinghaus and Cheatum, 1956:129).

Data on 574 adult deer road-killed during the winter period (December–March) indi-

TABLE 8.—AVERAGE MONTHLY ADULT SEX RATIO OF WISCONSIN ROAD-KILLED DEER, 1946–55

	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Total and Averages
Number of deer	86	74	173	340	531	503	306	210	292	673	978	241	4,407
Per cent male													
12 months	42	39	30[2]	32[2]	41	43	35[2]	36[2]	40	51[2]	60[2]	38[1]	45.0
10 months	42	39	30[1]	32[1]	41	43[1]	35	36	40	—	—	38	38.1

[1] Significant difference from the average in the same row.

[2] Highly significant difference from the average in the same row.

TABLE 9.—FALL SEX RATIOS OF ADULT DEER IN WISCONSIN

	Pre-hunting Shining[1]	Road-kill	Bow Hunting[1]	Gun Hunting[1]
Years involved	'40–54	'46–55	'48–54	'50–51
No. of adults	8,552	1,651	1,682	3,705
Per cent male	30	56.5	39	43
Males:100 females	42	130	64	77

[1] From Dahlberg and Guettinger (1956:92).

cate an average sex ratio of 57 males per 100 females, or 36 per cent males. Limited data from 311 adult deer winter trapped in Wisconsin from 1940 to 1952 gave a sex ratio of 50 males per 100 females, or 33 per cent males (Dahlberg and Guettinger, *op. cit.*: 93). There is no significant difference between these winter sex ratios.

Fawn–adult doe ratios.—For the reasons given in the preceding section on Sex and Age Ratios, possible breakdowns of available road-kill data, to show herd composition, are limited. As yet, no reason has been presented to prevent using the data to show the relative success of the breeding season as indicated by the fawn–adult doe ratio in a road-killed sample.

Based on fall-season road-kills only, the indicated average fawn production during the 10-year period considered was 1.02 fawns per doe (Table 10). This compares with 1.06 fawns at fawning time (May and June) in Wisconsin (Dahlberg and Guettinger, *ibid.*:85).

Fall fawn–doe ratios based on shining and bow-hunting samples do not differ significantly from the ratio derived from road-kills (Table 11), while the ratio based on legal gun-killed deer is significantly lower than the road-kill figure. In any-deer hunting seasons, hunters selectively shoot larger (adult bucks and does) deer (Severinghaus and Cheatum, *op. cit.*:67). Consequently, fawns appear in the shot sample in smaller numbers than they are present in the population.

The index value of this fawn–adult doe ratio, as shown in Table 10, is limited by the small size of the samples. Had the samples been larger, the fawn–adult doe ratio for each major type of deer range could have been determined and a population index expressed.

Potential Uses of Road-kill Data

Carcasses of road-killed deer can be used for a variety of purposes. New York workers have used road-kills to demonstrate that variations in the fecundity of does are related to differences in range conditions (Cheatum and Severinghaus, 1950) and to determine when deer breed (Cheatum and Morton, 1946). The potential value of using reported deer road-kills as an index of population size depends upon the number of animals involved and on the maintenance of a standardized recording and reporting system in which all animals or a constant proportion of the total victims are reported annually. I doubt that a reporting scheme can be developed and maintained in the field to meet this requirement. Numerous uncontrollable and inherent social variables influence such a scheme and limit its practicality. During the period of 1946 through 1955, reporting efficiency varied in Wisconsin despite the fact that the system was seemingly standardized. If a standardized record-collecting and reporting system is maintained, additional procedures to handle the deer could include (1) the determination of sex by internal characteristics in

TABLE 10.—INDICATED FAWN PRODUCTION CALCULATED FROM WISCONSIN DEER ROAD-KILLED IN AUGUST, SEPTEMBER, OCTOBER, AND NOVEMBER

	1946	1947	1948	1949	1950	1951	1952	1953	1954	1955	Ten-year Total
Number adult does	56	59	100	98	83	60	88	105	121	256	1,026
Number fawns	62	78	101	96	89	55	53	125	151	233	1,043
Fawns per 100 does	110	132	101	98	107	91	60	119	125	91	101.7
95% conf. limits	74–162	88–204	78–128	72–128	67–126	62–140	41–88	92–150	100–164	75–113	——

TABLE 11.—INDICATED AVERAGE FAWN PRODUCTION OF WISCONSIN DEER BASED ONLY ON FALL DATA

	Road-kill	Pre-hunting Shining[1]	Bow Hunting[1]	Gun Hunting[1]
Years	'46–55	'40–54	'48–54	'50–51
No. of deer				
Adult does	1,026	6,026	1,026	3,002
Fawns	1,043	5,408	896	2,091
Fawns:100 does	102	89	87	70
95% conf. limits	88.6–112.6	78.6–100.0	78.6–100.0	61.3–78.6

[1] Data from Dahlberg and Guettinger (1956:95).

those instances when external features are mutilated or unreliable, (2) the determination of age by using the tooth-wear scheme developed by Severinghaus (1949), and (3) the aging of fetuses as outlined by Dahlberg and Guettinger (*op. cit.*:246). Any investigation that depends only upon the physical condition of the deer examined can be conducted successfully using road-kills, providing sample sizes are adequate for the confidence limits desired.

SUMMARY

Records of 6,585 white-tailed deer reported killed accidentally by motor vehicles on Wisconsin highways from 1946 through 1955 were examined to determine their potential usefulness as population indices. Comparison of the trend of deer road-kills with the trend of other population indices indicated that, despite systematic corrections for variations in traffic pressure, these road-kill totals cannot be used as a precise index of annual changes in the deer population.

Annual and average seasonal sex ratios of road-killed fawns agreed with the national average sex ratio of 51.5 per cent male:48.5 per cent female. The 10-year fawn sex ratio suggested that male fawns may be less vulnerable to highway accidents than female fawns. Sex ratios of adult deer calculated from annual total road-kills did not represent the status of the surviving portion of the herd. Vulnerability of adults to accidents with motor vehicles varied between months.

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FIELD-FEEDING PERIODICITY OF BLACK AND MALLARD DUCKS

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During the fall and winter months, when ducks are congregated in flocks, their most conspicuous daytime activity is associated with obtaining food. In certain species this activity takes the form of flights from resting areas on bodies of water to upland fields where the birds feed on any one of several cultivated crops. Of the species that utilize upland feeding areas, the mallard (*Anas platyrhynchos*) and the pintail (*A. acuta*) have been given the most study. Little has been published concerning the field-feeding behavior of the black duck (*A. rubripes*).

Several aspects of these flights to upland areas are of importance in waterfowl management. One of these is the timing or periodicity of the flights. None of the papers describing the periodicity of these flights presents any quantitative data that would give the reader a clear picture of how much day-to-day variation occurs in this periodicity, or how closely the periodicity is correlated with the various environmental factors alleged to influence it. The present study has been an attempt to describe the periodicity of upland feeding in a quantitative manner and to discover whether there is any relationship between variations in this periodicity and certain social and environmental factors.

This paper is a contribution from the Ohio Cooperative Wildlife Research Unit and the Ohio State University Ornithology Laboratory: U.S. Fish and Wildlife Service, Ohio Division of Wildlife, Wildlife Management Institute, and The Ohio State University co-operating. I am grateful to Eugene H. Dustman and Loren S. Putnam for advice and encouragement throughout the course of the study. I am indebted to William B. McIntosh for statistical advice.

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THE STUDY AREA

This study was conducted at the O'Shaughnessy Reservoir and surrounding area. The reservoir, which was created by damming the Scioto River, lies about 10 miles northwest of Columbus, in central Ohio. It serves as a water-storage reservoir for that city. The reservoir has a maximum width of ¼ mile, is about 6.5 miles long and has a surface area of about 940 acres.

The reservoir is, in many ways, an ideal area for studying waterfowl populations. During the autumn and winter months, it holds sizable populations of black and mallard ducks. The east bank of the reservoir is paralleled by trails, that can be traversed in an automobile. The shore line is quite regular, with very few coves or bays that might serve as hiding places for ducks. There is virtually no emergent vegetation. These conditions are conducive to a rather thorough waterfowl census of the area.

As hunting on the reservoir is prohibited by the city of Columbus, the birds are sub-

jected to hunting pressure only at those times when they venture away from the reservoir and feed in the surrounding upland areas.

PERIODICITY OF UPLAND FLIGHTS

This study is limited to observations of mixed flocks of black and mallard ducks made during the months of November, December, and January of 1954, 1955, and 1956. All feeding flights were to cornfields that had been harvested with mechanical pickers.

As has been reported by other authors, e.g., Bellrose (1944), Hochbaum (1955), and Bossenmaier and Marshall (1958), it was found that ducks feeding in upland areas tend to concentrate their feeding flights into two daily periods. One of these is during the early morning; the other is during the late afternoon or evening. The birds were never observed to stay overnight in the fields.

The morning flights were studied by my waiting during the early morning hours at cornfields in which the birds were known to have fed the previous evening. This method was used because attempts to detect morning flights leaving the reservoir had shown that these flights occurred when the light was still too poor for observation.

Thirty observations of the arrival of ducks over feeding areas revealed that their time of arrival was rather constant in relation to light intensity, the ducks arriving as the eastern sky was just beginning to lighten. The light intensity at the time of arrival was, in each case, too low to be measurable with a photometer sensitive to light intensities of 0.1 foot-candle. The data on morning flights thus indicate that they are quite regular as to time of occurrence in relation to light intensity. Sowls (1955) has reported similar conclusions for the morning flights of ducks in southwestern Manitoba.

Afternoon flights were studied by watching the daily departure of ducks from the reservoir. The initiation of the flight for each day was recorded in minutes before sunset. The time of flight initiation varied greatly from day to day. The extremes for 91 observations were 9 and 205 minutes before sunset, the time of sunset, as published by the U.S. Weather Bureau, being converted to local time for these calculations. This variability in initiation of the flight is quite different from the precise departure of mallard ducks during the afternoon flight, as described by Bellrose (*op. cit.*). According to his description, "When shooting hours ended at 4:00 P.M. the ducks would leave the lakes and rivers at 4:00 P.M. in their daily flights to the fields." He further states that during the 1943 hunting season the evening flights to the cornfields started at about 5:00 P.M. daily.

TABLE 1.—POPULATION SIZE IN RELATION TO INITIAL FEEDING-FLIGHT TIME

Population Size	No. of Observations	Mean Feeding Time[1]	Extreme Feeding Times	Standard Error
0–1000	37	40	9–99	4
1001–2000	13	82	15–205	17
2001–3000	14	50	18–140	4
3001–4000	6	79	27–143	18
4001–5000	8	97	70–192	18
5001–6000	8	84	38–158	13
6001–7000	2	85	52–118	—
7001–8000	3	99	56–173	—

[1] Feeding time is recorded in minutes before local sunset.

POPULATION SIZE

It was soon noted that early afternoon feeding seemed to be associated with large populations and/or a high percentage of mallards in the population. Since another phase of the study required a careful census of the study area, it was decided to run correlation tests to determine if there was any statistical association between afternoon flight time and population size or between afternoon flight time and the percentage of mallards in the population.

Population data and time of flight initiation were recorded for 91 days (Table 1). During the course of this study the local population varied from less than 100 ducks to about 8,000. Whenever possible, the number of ducks present was determined by a direct count. The point at which direct counts became impossible was variable, being determined primarily by the com-

pactness of the rafts of ducks. Except when the rafts were extremely compact, it was possible to count populations of 4,000 ducks or less with considerable accuracy. When rafts were less compact, populations of 5,000 to 6,000 ducks could be counted successfully. Three to four hours were spent counting during each day.

Utilizing the available data for 91 days, a correlation coefficient of feeding-flight time in relation to population size was computed. This coefficient is +0.410 and is significant at the 0.01 level of probability. This suggests that there is a tendency for afternoon feeding flights to occur earlier as the size of the waterfowl population increases.

Why there should be an association between large populations and early feeding is impossible to answer without further information. I think it is proper, however, to speculate concerning some of the conditions that are associated with large populations and that might be conducive to early feeding.

During the course of the present study, the largest part of the local population was usually found feeding in one or in several adjacent cornfields. There was a tendency for feeding ducks to congregate in a relatively small area. As the population feeding in a field increases from several hundred to several thousand ducks, it would seem that increased competition might result in a decrease in the amount of food obtained per duck during a single feeding period. This is made even more likely by two other characteristics of field-feeding populations. First, the amount of time that the ducks actually spent in the fields was rather short. This was timed on 25 occasions and the mean feeding time was only 15 minutes, with extremes of 5 and 30 minutes. Second, the ducks did not spread evenly over the field while feeding but tended to concentrate in one part. Both of these characteristics would accentuate any effect that population size might have on feeding success. Possibly the amount of food obtained during the morning feeding period influences the time at which the next (afternoon) feeding period is initiated. The birds that are not so successful in filling their crops during the morning period are, perhaps, the ones that initiate the early afternoon flights.

It is probable that both internal and environmental stimuli play a role in eliciting these upland flights of ducks. At the present time the relative roles of these are not known. It is conceivable that the mutual stimulation associated with large populations would result in a lowering of the threshold of response to these stimuli. This would be analagous to mob psychology in humans and may also have some bearing on the present discussion.

INTERSPECIFIC COMPOSITION OF FLOCKS

Swinebroad (1956), in discussing 14 evening flights of black and mallard ducks says that "in 13 of these, all of the first group to take wing were mallards. This was felt to be true of 90 per cent of the evenings on which the initiation of flight was noted, even though it was not possible to record the data for every flight." My own impression is that when the initial flight from a mixed population of blacks and mallards is composed of one species, that species is the mallard. Usually, however, the initial flight is composed of both species, in which case it is usually predominantly mallard in composition. I have never seen an initial flight composed entirely of black ducks unless there were no mallards in the population.

Swinebroad's (*ibid.*) records of afternoon-flight initiation do not show nearly so many early afternoon feeding flights as were observed in the present study. While he did not attempt to evaluate flight time in relation to interspecific composition of the population, the populations were predominantly composed of black ducks during the course of his study.

Data on the percentage of mallards in the population and the time of flight initiation were available for 56 days of the present study (Table 2). These data and the foregoing observations suggest that the relative percentages of the two species in the population might have some effect on the

TABLE 2.—INITIAL FEEDING-FLIGHT TIME IN RELATION TO THE PERCENTAGE OF MALLARDS IN THE POPULATION

Per Cent Mallards	No. of Observations	Mean Feeding Time[1]	Extreme Feeding Times	Standard Error
0–25	9	29	9–51	16
26–50	26	41	9–190	7
51–75	16	72	16–205	13
76–100	5	82	42–99	10

[1] Feeding time is recorded in minutes before local sunset.

time of afternoon feeding. In order to clarify this possibility, a correlation coefficient of the percentage of mallards in the population in relation to the time of flight initiation was computed. This coefficient is +0.456, which is significant at the 0.01 level of probability. This suggests that, as the percentage of mallards in the population increases, there is an increase in the frequency of early afternoon feeding.

Why there should be an association between a high percentage of mallards in the population and early afternoon feeding cannot be answered without further information. My preliminary studies of the periodicity of activity of these two species under laboratory conditions suggest that the initiation of the second daily period of activity of the black duck is more dependent on the external cue of a decrease in light intensity than it is in the mallard (Winner, 1957). If this is true, the evening activity of the black duck would tend to be more regular in time of occurrence, at a lower light intensity and thus later in the day than that of the mallard.

The preceding discussion has indicated a possible relationship between time of initiation of afternoon feeding flights and both population size and species composition of the population. Since the size of the population and the species composition of the population both vary from day to day and from season to season, it is difficult to determine what the relationship of either of these variables to flight time would be if the other were constant. A comparison of the three variables (flight time, population size, and percentage of the population composed of mallards) by the method of partial correlation gives some concept of the relationship as it would be between any two of the variables if the third were held at a constant average.

Partial correlation coefficients were computed for the 56 days for which data on both population size and percentage of mallards in the population were available. The partial correlation coefficient for the relationship between feeding-flight time and population size, with the percentage of mallards held at a constant, is +0.355 for these data. The partial correlation coefficient for the relationship between feeding-flight time and the percentage of mallards in the population, with population size held constant, is +0.438 for these data. Both coefficients are significant at the 0.01 level of probability. The results of these partial correlation tests are in general agreement with those of the simple correlation tests, indicating that feeding time is related to both the number of ducks in the population and to the species composition of the population.

AIR TEMPERATURES

Air temperature might logically be expected to have some effect on the time of initiation of feeding flights. Kendeigh (1934) says, "As a general rule, birds are more active during cool weather than when it is hot and humid. Cool weather then can be expected to allow and encourage greater activity on the part of birds and to increase their daily food requirements."

Bossenmaier and Marshall (*op. cit.*) and Hochbaum (*op. cit.*), in studies of field-feeding activities of mallard and pintail ducks in Manitoba, report that early afternoon feeding flights are associated with cold weather. Bellrose (*op. cit.*), in discussing the field-feeding behavior of mallard ducks in Illinois, says, "During cold, blustery weather, when the thermometer was below freezing, mallards forsook their morning and evening routine, feeding throughout the day in fields close to their rest lakes."

During the autumn and winter of 1956, I recorded hourly air temperatures from 9:00 A.M. to 5:00 P.M. at O'Shaughnessy

Reservoir. Hourly temperature records were not maintained for the first 2 years of the study. However, the U.S. Weather Bureau publishes hourly temperature records for the Columbus, Ohio, area. Since the study area lies only 10 miles northwest of Columbus, it seemed unlikely that there would be much variation between the temperatures of the two areas. A comparison between the mean daily temperatures computed from the study area data and those computed for the same days from the Weather Bureau data revealed that the differences between the two were very slight. Thus, mean daily temperatures computed from Weather Bureau data were used in evaluating the 1954 and 1955 seasons.

Mean daily temperatures and time of initiation of afternoon feeding flights were available for 103 days of the study. Flight time is recorded in minutes before sunset. A correlation coefficient of flight time in relation to mean daily temperature was computed for these data. This coefficient is –0.210 and is not significant at the 0.05 level of probability. These data indicate that temperature played a small role, if any, in regulating the time of afternoon feeding flights during the 3 years of this study.

LIGHT INTENSITIES

The flights of ducks are characteristically initiated during periods of low or changing light intensity. One might suspect, then, that low or changing light intensities are stimuli to flight activity in ducks. Potentially, light intensity could stimulate flight activity in several ways. Absolute values of light intensity are possibilities as stimuli to activity, i.e., flight may be initiated when a certain level of intensity is reached, or it may be initiated within a certain range of light intensities. In the present study, the first afternoon flights of the day were initiated at intensities varying from 2.2 to 1,000 foot-candles. Only during the 1956 season did I have a photometer that would measure intensities greater than 250 foot-candles. It is possible that some flights were initiated at intensities even higher than 1,000 foot-candles in 1954 and 1955. Such a wide variation in light-intensity values makes it doubtful that there is a relationship between the initiation of feeding flights and absolute values of light intensity.

Possibly the threshold of response of ducks to light intensity varies under different conditions. Several environmental and social factors might affect this threshold. The apparent relationship between population size and flight time may be due to the threshold of response to light intensity changing as the population size changes. Data on both light intensity at flight initiation and population size were available for 42 days of the present study. The correlation coefficient for these two variables is +0.198, which is not significant at the 0.05 level of probability. This test does not indicate a relationship between light intensity at initial flight time and populaton size.

A further possibility is that the threshold of response to light intensity varies with the rate of change of intensity. For example, a decrease in intensity from 1,000 to 100 foot-candles in a matter of minutes might be an effective stimulus, whereas the same magnitude of decrease over several hours might not be effective. At the slower rate of decrease, the intensity would drop to a lower value before it functioned as an effective stimulus. This would result in considerable day-to-day variation in the light intensity at which flight was initiated. The data from this study are not conducive to testing such a hypothesis.

TIME OF LEGAL HUNTING HOURS

The duck hunter has long believed that the time of initiation of afternoon field-feeding flights of waterfowl, during the hunting season, was more or less regulated by the time of legal shooting hours. This concept, in its most extreme expression, states that waterfowl do not leave their resting places on bodies of water until after shooting hours have ended.

There are several difficulties associated with an attempt to determine whether hunting pressure plays a role in regulating the periodicity of field-feeding flights. There is a complete lack of published quantitative

data describing the periodicity of field feeding. Obviously, it is difficult to determine the relationship between environmental factors and a periodicity that has not been adequately described.

The relative hunting pressure to which field-feeding waterfowl are subjected is difficult to determine. If hunting pressure is a factor in regulating the time of upland feeding, its importance would probably vary from one area to another, depending on the relative magnitude of the hunting pressure in the different areas. This is further complicated by the fact that many ducks in areas of light hunting pressure have previously been subjected to heavier hunting pressure in other areas. Quantitative data of feeding-flight periodicity for those years during which there was a closed waterfowl season might be enlightening. Unfortunately, such data are not available.

Any apparent relationship between the time of field feeding of the various species of ducks and the time at which shooting hours end may be merely a coincidence. The true relationship may be with some natural phenomenon, e.g., time of sunset, that happens to change in proportion to the change in the daily time of shooting hours. Since legal shooting hours end at a constant time in relation to the time of sunset, shooting hours must vary directly as the time of sunset varies.

Data from the present study provide information on afternoon feeding-flight time for 79 days during open waterfowl season. The mean flight time for these days was 15 minutes before the end of shooting. However, the standard error is 179 minutes before the end of shooting hours, an indication of the extreme variability of feeding-flight time when considered in relation to the time at which daily shooting hours end. The extreme flight times for these data are 42 minutes after to 115 minutes before the end of shooting hours. There is certainly not much evidence of a relationship between these two variables evident in the above data. Considering the fact that quantitative data of feeding-flight time in relation to the cessation of shooting hours have not been published for other areas, it would seem that caution should be used in assuming a relationship between feeding-flight time and the time at which shooting hours end.

SUMMARY

The periodicity of field feeding of mixed populations of black and mallard ducks was studied over a 3-year period. The time of initiation of the first daily afternoon flights varied from 9 to 205 minutes before sunset. These flights were initiated under light conditions varying from 2.2 to 1,000 foot-candles. There was a significant correlation between the time at which afternoon flights were initiated and the size of the population. Also, there was a significant correlation between the time of afternoon flight and the percentage of mallards in the population. Initiation of afternoon flight occurred earlier in relation to time of sunset as the population size and/or the percentage of mallards in the population increased. No relationship was found between the time at which afternoon flights were initiated and either the mean daily temperature or the time at which daily waterfowl shooting hours ended. There was no relationship between the initiation of afternoon feeding flights and absolute values of light intensity, but a more complex relationship between the two variables is possible.

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SOME POPULATION MECHANICS OF THE AMERICAN COOT

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This paper is concerned with the annual mortality rate, age composition, and migratory distribution of the population of American coot (*Fulica americana*) contributing to the hunting kill in the northern Mississippi Flyway. It also evaluates three possible aging techniques and one sexing technique.

Most studies of the coot (Sooter, 1945; Gullion, 1954; Kiel, 1955; and others) have dealt with the local breeding activity of the species, its large clutch size, and its high nesting success. Kiel and Hawkins (1953) described the status of the coot in the Mississippi Flyway on the basis of relative kill and winter inventory.

With the exception of the mallard (*Anas platyrhynchos*), the coot has in recent years generally exceeded each species of waterfowl in numbers bagged in the Mississippi Flyway (Williams, 1953; Crissey, 1954, 1955, 1956, 1957). This status in the bag indicates a potential need for management of the species and for such basic information as estimates of the population's productivity and over-all mortality. Reeve and Pimlott (1950) have attempted to obtain an age and sex ratio for coots bagged at Lake Puckaway, Wisconsin. They found that some females possessed small bursae and adult-appearing ovaries. As the observed percentage of juveniles (90 per cent) seemed too high for normal production, these authors suggested differential migration by age groups.

Working with small samples, Gullion (1952) was unable to demonstrate regression of the bursa with age or season. As an alternative method of aging, he suggested the use of tarsal color, and found a reasonable percentage of young (79 per cent in a sample of 79) in a California population. The further testing of this tarsal-color method and the determination of age structure in the bag were important objectives of the study reported here.

General Aspects of the Population

Banding records.—Recoveries of coots banded in eastern North America from 1923 to 1947 inclusive were used to compute a survival rate for the population contributing to the regional kill. These birds had, for the most part, been banded in Illinois and Louisiana. Most of the 248 recoveries of coots banded in Illinois represent birds trapped by John Jedlicka at McGinnis Slough, a refuge area controlled by the Forest Preserve District of Cook County, Illinois. They were banded largely in October and November and were not aged by the bander. F. C. Bellrose also banded coots at many localities in Illinois. Most of the Louisiana-banded birds used in my distributional analysis were banded by E. A. McIlhenny at Avery Island, Louisiana. Birds banded in the Prairie Provinces and the Dakotas were trapped mostly during August and September, and most of them were aged by the bander. This aging was presumably based on the distinct juvenile plumage of the "locals" or juveniles at the time of banding.

The technique of determining the survival of an adult population described by Hal-

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TABLE 1.—MONTHLY DISTRIBUTION OF BAND RECOVERIES OF BIRDS BANDED 1923–47, INCLUSIVE

Where and When Banded	Number Recovered	When Recovered					
		Sept.	Oct.	Nov.	Dec.	Jan.	Other[1]
I. BANDED OUTSIDE OF ILLINOIS							
April	7	1	1	2	0	0	3
May	5	1	1	0	1	1	1
June	6	0	3	2	0	1	0
July	31	3	8	10	8	0	2
Aug.	135	7	57	31	23	5	12
Sept.	115	7	52	30	15	3	8
Oct.	8	0	5	5	2	0	1
Totals	307	19	127	80	49	10	27
II. BANDED IN ILLINOIS							
Mar.-Apr.	12	0	2	5	0	1	4
Sept.	16	0	7	5	1	0	3
Oct.	146	2	34	49	28	20	13
Nov.	74	2	8	29	26	4	5
Totals	248	4	51	88	55	25	25
III. BANDED AS JUVENILES (aged by bander)							
Rec. as juv.	138	13	73	30	17	2	3
Rec. as ad.	36	1	6	11	5	2	11

[1] Includes February to August recoveries.

dane (1955), and used in the present paper, attempts to fit a linear equation to an observed series of banding records assumed to represent mortality (d_x). The estimate of survival rate is made by a maximum-likelihood estimate. The completed cohort form that I studied consisted of recoveries of coots banded up to and including the year 1947.

Survival and expected age distribution.—The band-recovery data are summarized in Table 1. All materials relating to mortality rate are derived from the adults in this series, except those for which no date of recovery was specified.

The maximum-likelihood method of estimating adult survival rate (Haldane, *ibid.*) indicates that the combined recovery series of 139 birds banded in the Prairie Provinces, the Dakotas, Minnesota, Iowa, and Illinois has an average annual survival rate of 43 per cent with a 2-standard-deviation interval of ± 6 per cent. The X^2 comparison for testing linearity in the series (Haldane, *ibid.*) does not suggest a significant departure (Table 2).

Of the 174 birds banded as known juveniles in the Prairie Provinces and the Dakotas and subsequently recovered, 138 (79 per cent with a 2-standard-deviation of ± 4 per cent) were recovered in the first hunting season to which they were subjected. This percentage is essentially an estimate of the proportion of young in the bag over a wide geographic area and does not represent the age composition of the population. The estimate is not time and place specific and represents a response to hunting pressure in the 1940's and early 1950's (when most of the recoveries were reported). The predicted bag composition in a presumably stable population is 79 per cent young, 12 per cent 1-year-olds, and the remaining 9 per cent older birds. The 12 per cent was obtained by taking the product

TABLE 2.—COMPARISON OF EXPECTED AND OBSERVED BAND RECOVERIES FOR THE COMPOSITE ADULT SURVIVAL ESTIMATE

Age Interval	Number Dead (d_x)		Chi Square
	Reported	Expected[1]	
1	82	79.1	0.107
2	31	34.1	0.270
3	14	14.7	0.036
4–8	12	11.1	0.081
Totals	139	139	0.494[2]

[1] Calculated after Haldane (1955).
[2] $0.8 > P > 0.7$.

FIG. 1. Locations at which coot band recoveries are concentrated during the hunting season.

of 21 per cent adults in the bag (Table 1, part III) and the adult mortality rate. If, under similar limitations, the monthly composition of the bag (Table 1, part III) is computed, the percentage of juveniles becomes 92 ± 6 per cent for October and 73 ± 11 per cent for November to January recoveries.

Distribution.—The locations at which band recoveries from hunting are reported are not random in distribution, but tend to be concentrated (Fig. 1). "Major kill concentrations" in the accompanying map are those localities in which ten or more recoveries were reported from a single lake or its immediate vicinity. "Minor kill concentrations" are taken as those locations where a similar number of recoveries was concentrated but over a more extensive area. This concentration of coot hunting, as well as gross variations in hunter density (Hickey, 1951), introduces a bias into the percentages of recoveries as indices of movement between states (Table 3). This bias may be eliminated in part if relative values within each state are compared and the trend rather than the absolute values compared.

The percentage of out-of-state recoveries for birds banded in Illinois and the Southeastern States is lower in the region from North Dakota to Texas than is the same percentage of recoveries of Louisiana-banded birds. In the recovery region from Minnesota to Louisiana, these percentages are slightly less contrasting. The region from Wisconsin to Alabama contains 25 per cent of the out-of-state recoveries of birds banded in Illinois and 32 per cent of those banded in Louisiana. In contrast, 73 per cent of the recoveries of southeastern-

TABLE 3.—SUMMARY OF RECOVERIES OF COOT BANDED IN ILLLINOIS, LOUISIANA, AND THE SOUTHEASTERN UNITED STATES

Where Banded	Illinois	Louisiana	Southeast
Numbers recovered			
Within state	125	673	32
Out of state	205	293	67
Total	330	966	99
Where recovered	**Percentage of Out-of-state Recoveries[1]**		
Yukon	0	0.5	0
Prairie Provinces	0.5	6.5	4
N. and S. Dakota	0.5	4.5	0
Nebr. to Tex.	3.0	8.5	0
Mexico	0.5	0.5	0
Central America	0.5	0.5	0
Minn., Ia.	2.5	25.0	9
Mo., Ark.	0.5	14.0	0
Louisiana	10.5	—[2]	4
Wisconsin	7.0	4.5	24
Illinois	—[2]	10.0	24
Michigan	1.5	1.5	9
Indiana	4.0	2.0	7
Ohio, W. Va.	1.5	0	9
Kentucky	2.0	0.5	0
Tennessee	2.0	8.5	0
Miss., Ala.	7.0	5.5	0
Newfoundland	0	0.5	0
New England	0.5	0	0
N.Y., Pa., N.J.	1.0	0	7
Md., Del.	0.5	0	1
Virginia	5.0	0.5	–[2]
N. and S. Carolina	6.0	0.5	–[2]
Georgia	3.0	0.5	1
Florida	27.5	1.5	–[2]
West Indies	7.5	1.5	1

[1] These are carried to one decimal place for comparison only.

[2] States of banding are not included in this table.

banded birds were reported in the northern part of this region (Wisconsin, Michigan, Illinois, Ohio, Indiana, West Virginia). From this distribution of band recoveries and the known scarcity of breeding coots in eastern North America, I conclude that the birds wintering in the Southeast migrate largely through the northern Mississippi region.

AGE CHARACTERS

Materials and methods.—During November 1956, I obtained 101 specimens of coot accidentally killed in muskrat traps at Horicon Marsh in southeastern Wisconsin. These birds were frozen when received at the marsh management headquarters. I dissected them at a later date and took internal and external measurements. In 1957, when I examined 869 birds in hunters' bags, only external measurements were taken. The bursa of Fabricius in the trapped birds was probed before dissection and its length determined with a millimeter rule during dissection. Birds obtained from hunters were probed but not dissected, the probe being scored at 2-mm. intervals; this resulted in a clustering of recorded bursal depths at even-numbered millimeters.

In my study of Gullion's (1952) tarsal-color technique, I compared all tarsi with a color standard and measured the colors on a quantitative basis. For this purpose, Munsell color charts of the 40-hue "student" set proved to be an adequate and convenient standard. This technique (Miller, 1958) allows the numerical recording of hue, value, and chroma of a pigment. *Hue* refers to the spectral composition of the color, *value* indicates the proportion of incident light reflected, and *chroma* indicates departure from a neutral gray. In this paper, the Munsell hue of 27.5 is called orange-yellow, hue 30 is yellow, hue 32.5 is yellow-green, and hue 35 is green. Higher numbered hues in the Munsell scale that were encountered in coot tarsi were blue or gray-greens.

In the sample of 869 birds collected during 1957, the color of the tibia was recorded in addition to the tarsal color. To study color changes during storage, in 1956, I removed legs from frozen birds and recorded the color immediately and at intervals for several weeks while the legs were stored without refrigeration. Freshly thawed and freshly collected legs did not show a definite difference in color distribution.

The callus of the frontal shield has been found by Gullion (1951) to respond in size to gonadal hormones. This response suggests the use of callus size as an index of gonadal activity in the specimen. As a means of investigating the callus as an index of age, the length and width of the callus were taken with a millimeter rule in 1956 and with the bursal probe in 1957.

Results.—In fresh legs I found that the toe lobes of coot were light bluish-gray (52.5–9.5/2, the fraction representing value and chroma in the Munsell system). Fresh tarsi possessed colors from orange-yellow (27.5) to bluish-green (47.5) in 964 tarsi examined for color. Ninety-nine per cent of these tarsi were green, yellow-green, or yellow (Table 4). In all analyses, I grouped

TABLE 4.—DISTRIBUTION OF LEG COLOR OF COOTS COLLECTED IN WISCONSIN AND ILLINOIS IN 1956 AND 1957

Where Collected			Horicon Marsh			Grass Lake
Year			1956	1957		1957
Date			Nov.	Oct. 1	Oct. 5	Oct. 19
Sample Size			95	187	109	573
Leg Color			Percentage of Sample			
Class	Color	Hue				
I. INITIAL GROUPING						
1	Green	35	54	36	60	12
	Yel.-gr.	32.5	29			
2	No red[1]			40	20	31
3	Red[1]			14	14	22
4	Yellow	30	17	10	6	35
II. COMBINATIONS OF ABOVE CLASSES						
a.	1		54	36	60	12
	2,3		29	54	34	53
	4		17	10	6	35
b.	1,2			76	80	43
	3			14	14	22
	4			10	6	35
c.	1,2,3		83	90	94	65
	4		17	10	6	35

[1] Color of the tibial segment.

TABLE 5.—TABLE OF CONTINGENCY BETWEEN TARSAL HUE AND BURSAL DEPTH

TARSAL HUE		BURSAL DEPTH[2] (in mm.)			
Approx. Color	Hue No.[1]	0–19	20–29	30–40	Total
Yellow	27.5 and 30	23	5	2	30
Yellow-green	32.5	16	49	13	78
Green	35	1	5	71	77
Totals		40	59	86	185

[1] The tarsal hue was measured as the hue-circuit number of the Munsell color chart most closely matching the color of the tarsus.

[2] Probed depths from birds collected at Horicon Marsh on October 1 and 5, 1957.

bluish-green tarsi together with green tarsi and orange-yellow together with yellow. These bluish-green and orange-yellow colors were rare and represented distinctly young and adult birds.

Average colors for each of the main hues were green (35–6.2/6.2), yellow-green (32.5–6.0/6.6), and yellow (30–6.0/7.0). When frozen tarsi were examined at intervals after thawing, the value and chroma decreased until a neutral black was reached in about 2 weeks. No change in hue was apparent up to 7 days, after which the value and chroma levels made this determination difficult.

Tarsal hue and bursal depth were found to be associated in a sample of 185 birds (Table 5), the calculated X^2 (152.62) being significant at the 0.001 level of probability. The Pearson Coefficient of Contingency (0.638) for this table is 80 per cent of the maximum possible for a three by three table (Yule and Kendall, 1950).

I handled 12 birds in which the callus appeared to be deformed. These birds were otherwise normal, healthy adults, and many had enlarged frontal shields. Two of the 970 birds handled lacked the callus entirely and resembled the European coot (*Fulica atra*) in this respect, but both birds had the red bill-tip marking of the American coot. Both of these birds had very large frontal shields.

I was able to divide the birds with yellow-green tarsi into two groups on the basis of the presence or absence of red pigment in the tibia. Birds with green tarsi did not have red tibias, while all those with yellow tarsi did.

As a character independent of color, the approximate width of the callus was used to compare two groups of 207 birds with yellow-green tarsi (Table 6). The calculated X^2 for this table (102.87) is significant at the 0.001 level. The distribution of the callus width in birds with yellow-green tarsi and a red tibia is more similar to those with yellow than green tarsi. The converse is true of birds with yellow-green tarsi and green tibias. Since Gullion (1952) found that the callus increases in size under the influence of gonadal hormones, it appears that birds with red tibia probably have greater gonadal hormone levels than those with green tibia.

Discussion.—The percentage of young in all recoveries (79 ± 4 per cent) is an estimate of the over-all bag composition, but is not an estimate of population composition or juvenile mortality rate. If one assumes a balanced sex ratio and that all coots breed at the age of 1 year, the adult mortality rate of 57 ± 6 per cent indicates that an average of 1.14 young must survive to breeding age from each pair's productivity if the population remains stable. If only one brood is raised and the average clutch size is 9.9 (Kiel, *op. cit.*), the mortality from egg to first breeding may be as high as 88 per cent at population stability. A smaller clutch size of 8 would still allow an egg-to-first-breeding mortality of 85 per cent. These figures are based on what appear to

TABLE 6.—TABLE OF CONTINGENCY BETWEEN TARSAL HUE AND THE WIDTH OF THE CALLUS

COLOR OF TARSUS		WIDTH OF THE CALLUS[2] (in mm.)			
Approx. Color	Hue No.[1]	6–7	8–9	10–12	Totals
Yellow	30	3	41	84	128
Yellow-green	32.5				
Tibia red		4	46	53	103
Tibia not red		31	54	19	104
Green	35	23	29	4	56
Totals		61	170	160	391

[1] Recorded as the hue-circuit number of the Munsell chart most nearly matching the tarsus.

[2] Measured to the nearest millimeter only.

be good estimates of the parameters involved. Kiel's statistic definitely deals with completed clutches, while in the reports of other authors this does not seem to be as clearly evident.

The date-specific age composition of band recoveries indicates that 92 per cent of the birds bagged by hunters in October are juvenile. The 90 per cent juvenile composition of the bag found by Reeve and Pimlott (*op. cit.*) in Wisconsin does not seem to be excessive by comparison. It is unlikely that this 92 per cent represents the actual proportion of juveniles in the coot population, as this requires that all the young from two full clutches of 11 eggs survive to the hunting season for each adult pair in the recovery or bag sample at this time. Kiel (*op. cit.*) reports the highest average clutch size (9.9) for the coot in the literature. Although Gullion (1954) has reported many multiple broods, these have not been definitely recorded in the region in which I studied. It seems, therefore, that differential migration or hunting pressure, or both, must account for such a high ratio of young to adults in the bag in this region.

Gullion (1952) assumed that the green, yellow-green, and yellow tarsal-color groups he identified were young, yearlings, and old birds, respectively. If this were true, we would expect the frequency of green-legged birds in the bag to be comparable to the expected values obtained from banding data. From Table 4, part IIa, it is evident that the percentages of green-legged birds are all significantly less than the expected range (92 per cent for October recoveries or 79 per cent for all recoveries). In Table 4, part IIb, the splitting of hue 32.5 into two segments and the joining of the nonred-tibial segment to hue 35 increase the percentage of "juvenile" to the vicinity of the overall recovery percentage (79 per cent) in the October 1 and 5 samples. By lumping all of hue 32.5 with hue 35 (Table 4, part IIc), the possible percentage "juvenile" is close to the expected October value in the October 1 and 5, 1957, samples, and that of the 1956 sample is then only slightly lower. Thus it appears likely that the green and yellow-legged birds were correctly assumed by Gullion (*ibid.*) to consist of young and adult birds respectively. The results of my study suggest that the yellow-green-legged birds are not yearlings as suggested by Gullion (*ibid.*) but may be composed either of young and adult birds (that can be separated by tibial color) or they may all be young birds of different hatching dates. The study of this leg-color group with known-aged birds offers promise as a further research project on this species.

SEX CHARACTERS

Methods.—Gullion (1952) has suggested use of the length of the tarsus (tarsometatarsus) and middle toe as a means of separating the sexes in this species. This measurement was found to give the best separation of the physical measurements recorded and was taken in my study with the inclusion of the claw of the middle toe for easier measurement. I recorded this length with a millimeter rule after removing the leg from the body. In dissected birds, I examined and measured the gonads for true sex and gonad size.

Results.—It was possible to separate the dissected sample into known-sex segments that could be used as a basis for evaluating methods of sexing by external measurements. The length of the tarsus (tarsometatarsus) and middle toe with claw was an external measurement that gave good separation. Gullion (1952) suggested the use of this measurement without including the claw. Of the 49 males I measured, 86 per cent possessed a tarsus–toe length of 140 mm. or greater. Of the 52 females, 84 per cent had a tarsus–toe length of 139 mm. or less. For this separation point, the mean and standard deviation of each sex segment gave a t value indicating that 85 per cent of both sexes would be correctly separated by a separation at 139.5 mm. This separation point differs from that given by Gullion by the mean length of the claw of the middle toe.

In the 1956 sample of coot taken in muskrat traps, it was apparent that the sex ratio of two tarsal-hue categories was signifi-

TABLE 7.—HUE CLASS AND TARSUS-TOE LENGTH CLASSIFIED ACCORDING TO KNOWN SEX

COLOR OF TARSUS		NUMBER OF SPECIMENS			
Approx. Color	Hue No.[1]	Male	Female	Per Cent Male[2]	Per Cent with Tarsus-toe of 140 mm. or More
Yellow	30	8	8	50±25	44
Yellow-green	32.5	20	8	72±18	61
Green	35	16	34	32±14	40
Totals		44	50	47	48

[1] Recorded as the hue-circuit number of the Munsell chart most nearly matching the tarsus.

[2] With confidence limits, assuming that males comprised 50 per cent of the population from which the sample was drawn.

cantly different from 50 per cent. In hue 35 (green), females predominated; in hue 32.5 (yellow-green), males predominated (Table 7).

Discussion.—The overlap of sex segments with respect to tarsus–toe length introduces a bias in the computation of sex composition. This bias may be corrected algebraically by the formulae:

1) (Per cent 140 mm. or more) = (per cent male) (male accuracy) + (per cent female) (female error)

2) $$(\text{Per cent male}) = 100 \times \frac{(\text{fraction 140 mm. or more}) - (\text{female error})}{(\text{male accuracy}) - (\text{female error})}.$$

The values obtained from the hue-35 segment of the dissected sample give the following estimates for these two expressions:

1) $38.4 = (32)\ (0.86) + (68)\ (0.16)$

2) $$34.3 = 100\ \frac{0.40 - 0.16}{0.86 - 0.16}.$$

The close agreement of these values to the observed 40 per cent for green-legged birds in Table 7 suggests the adequacy of the correction factors which should, however, be refined by study of much larger samples than I used. Apparent variations in sex ratio were encountered in the birds that I sampled (Table 8).

In all these comparisons, the sample taken on October 19, 1957, from Grass Lake, Illinois, is aberrant. The local residents of this area reported to me a departure of coots there on the previous evening. This report suggests the occurrence of a sex- and age-specific migration and gives a possible explanation of the aberrant statistics that I obtained there.

TABLE 8.—COMPARISON OF OBSERVED AND IMPLIED SEX RATIOS OBTAINED IN MIDWESTERN SAMPLES OF COOT

Sample Date Taken	Sample Size	Per Cent Male	Per Cent with Tarsus-toe 140 mm. or More
Oct. 14–15, 1949[1]	541	49±4	—
November 1956	101	47±10	48±10
October 1, 1957	187	—	41±7
October 5, 1957	109	—	38±8
October 19, 1957	573	—	57±4
All 1957	869	—	51±3

[1] Reeve and Pimlott (1950).

In the known-sex sample, the length of the tarsus and middle toe with claw separated sexes with 85 per cent accuracy, in contrast to 82 per cent obtained by Gullion (*ibid.*) using this measurement without the claw. By using additional characteristics including behavior, Gullion (pers. comm.) raised his over-all sexing accuracy to 88 per cent.

SUMMARY

The maximum-likelihood method of Haldane (1955) indicated an average adult mortality rate of 57 ± 6 per cent for 139 coots banded in eastern North America. The percentage of young in the entire recovery series was 79 ± 4; in October recoveries, 92 ± 6 per cent; and in November to January recoveries, 73 ± 11 per cent. The egg-to-first-breeding mortality rate is suggested to lie between 88 and 85 per cent. There is a strong association between bursal length and the tarsal-color character suggested by Gullion (1952). When Munsell color charts were used to record leg color, the percentage of green- and yellow-green-legged birds gave a percentage "juvenile" of 90–94 per cent in 296 coots collected in Wisconsin in October 1957. This grouping agrees with the expected value better than only green-legged birds, as suggested by

Gullion (*ibid.*). The length of the tarsus and middle toe with claw was found to be a good means of sexing the coot, just as Gullion (*ibid.*) found, excluding the claw. In a known-sex sample of 101, the accuracy of this criterion was 85 per cent and the percentage of males was 47. A formula for correcting bias due to sexing errors, given without algebraic proof, indicates that the tarsus–toe length may give accurate sex ratios when correction factors can be based on larger samples. Banding data and the scarcity of the coot in the Northeast suggest that coots wintering on the southeast Atlantic Coast migrate through the northern Mississippi Flyway.

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ESTABLISHMENT AND SPREAD OF THE WILD TURKEY IN SOUTHWESTERN MICHIGAN[1]

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One of the dreams of many midwestern sportsmen and conservationists is to see the wild turkey (*Meleagris gallopavo*) again in this region—if not as a game bird, at least as a member of the wildlife community. We can now report realization of the latter in the successful establishment of wild turkeys in southwestern Michigan. In this paper we give special attention to the occupation and extension of range during 5 years following their release.

Wild turkeys, once fairly common south of an Allegan County–Saginaw Bay line, disappeared from Michigan about 1900 (Barrows, 1912). The 51,000-acre Allegan Forest area, located within 100,000 acres of hardwood–pine forest in western Allegan

[1] A contribution from Federal Aid to Wildlife Restoration funds, under Michigan Pittman-Robertson Project W-89-R. The writers acknowledge the helpful advice of Charles E. Friley, Jr., biologist-in-charge of the Swan Creek Wildlife Experiment Station, and the work of Clayton H. Douville, project leader from 1954 to 1956.

County, seemed the most favorable location for restocking. The habitat here is similar in many respects to that recommended for wild turkey management in Pennsylvania (Kozicky and Metz, 1948).

HABITAT

Typical plants of eastern wild turkey range, such as white oak (*Quercus alba*), black oak (*Q. velutina*), red oak (*Q. rubra*), beech (*Fagus grandifolia*), black cherry (*Prunus serotina*), flowering dogwood (*Cornus florida*), wild grape (*Vitis* spp.), and greenbrier (*Smilax rotundifolia*), occur in the Allegan Forest area. A variety of foods is present.

Oak woodland occupies 61 per cent, conifers 10 per cent, and openings 8 per cent of the 50,902 acres of state and private land within the Allegan State Forest project boundary (Table 1). For wild turkey range, Pennsylvania (Kozicky and Metz, *ibid.*) recommends 60–80 per cent oak woodland, 10–15 per cent conifers, and 5–30 per cent openings. The Allegan Forest has barely enough conifers and openings. Twenty-seven per cent of the oak forest consists of red, white, and black oaks, 4 to 12 in. d.b.h. There is slightly more middle-aged oak timber on the Allegan area than the recommended minimum of 25 per cent. Since 30 per cent of the woodland is oak, oak–aspen, and mixed hardwood saplings, we have the 10–15 per cent needed as escape cover. Lakes, streams, and springs provide an ample source of water.

Actually 39,081 acres in this area are state-owned—32,415 acres of state forest and 6,666 acres in the Swan Creek Wildlife Experiment Station. Thus, the state controls an area approximately 13 times larger than the minimum of 3,000 acres suggested for turkey range by Pennsylvania.

THE RELEASE

The wild turkey stock from which we obtained our birds was developed by the Woodmont Rod and Gun Club of Hancock, Maryland. This stock originated from "three-fourths-wild" hens serviced by wild gobblers. Our 50 turkeys and 400 turkey eggs came from the Allegheny Wild Turkey Farm of Julien, Pennsylvania, in 1954.

TABLE 1.—COVER TYPES OF THE ALLEGAN STATE FOREST PROJECT AREA

Cover Type	Acres	Per Cent
Oak	30,916	60.6
Bottomland hardwoods	6,136	12.4
Upland conifers	5,000	9.7
Openings	3,880	7.5
Poplar	2,220	4.4
Oak–aspen	1,255	2.5
Marsh	891	1.7
Bottomland conifers	237	0.5
Mixed hardwoods	367	0.7
Totals	50,902	100.0

On March 23 and 24, 1954, Game Division personnel released the 50 turkeys at six sites in the Allegan Forest area. This release consisted of 10 yearling toms, 2 two-year-old toms, and 38 yearling hens—2 toms and 6 or 7 hens at each site.

At our state game farm at Mason, Michigan, the 400 eggs were incubated. From these on September 8 and 10, 1954, we released 152 more fourteen-week-old turkeys (89 females, 63 males), approximately 9 hens and 6 toms at each of 10 sites. All of the turkeys released bore leg bands and were in good condition.

Reactions of the birds were similar after each release. There followed a period of wandering until they found favored forest locations. Some turkeys joined domestic poultry flocks. During the winter, well-meaning farmers and other local residents fed the birds.

NESTING

In the spring, some wild turkeys attempted to mate with domestic birds. At least one such attempt was successful. In 1955 we sent to the state game farm the unbroken eggs from a nest destroyed in hay mowing. The five chicks successfully raised were hybrids.

Of 15 nests observed or reported between 1955 and 1957, the earliest contained eight eggs on April 18. For a nest with 18 eggs that hatched on May 26, the indicated date on which laying began was April 1. We

TABLE 2.—WILD TURKEY BAND RECOVERIES IN ALLEGAN COUNTY, MICHIGAN

Days since Release	DISTANCE IN MILES FROM RELEASE SITE					
	0–2.0	2.1–4.0	4.1–6.0	6.1–8.0	8.1–10.0	Totals
0–200	7	4	1		1	13
201–400		3		1		4
401–600	1		1			2
601–800	1					1
801–1,000		1				1
1,001–1,200	1					1
Totals	10	8	2	1	1	22

found the greatest number of nests in June. Seven nests were in hay, pasture, or other grassy areas, and the others in various oak types and an orchard. Eggs in three nests hatched. Predators destroyed four nests and hay mowing two more. We do not know the fate of the remaining six.

Broods declined in size from an average of 8.4±4.1 poults in June to 6.0±3.1 in August. This decline reflects normal summer losses. The actual minimum numbers of full broods observed for the four summers from 1955 to 1958 were 21, 23, 32, and 29, respectively.

SURVIVAL

Since the release, we have recovered 19 banded and 26 unbanded dead birds. The causes of death were: suspected poaching 8, possible predation 6, automobile 6, train 5, unknown disease 3, blackhead 3, hay mowing 1, unknown 12, and 1 shot for scientific examination. The operator of a domestic turkey farm captured three other banded birds. We could not find one banded bird that was reported to be dying.

Poaching was probably the greatest cause of loss. Officers actually apprehended and sentenced only one poacher. Many hunters use the Allegan Forest area heavily during the hunting season, and most illegal shooting losses occur incidental to other hunting.

Fifty-nine per cent of all band recoveries (Table 2) occurred in the 3 months following release. The average recovered banded bird lived approximately 7.5 months and moved 2.6 miles from the release site (Table 2).

RANGE EXTENSION AND POPULATIONS

While band returns indicated initial extremes of range extension up to 10 miles from the point of release, the "established" range—the area where we actually found broods—expanded at a slower annual rate. From a release area of 26 square miles, our wild turkeys increased their range at an average rate of 16 square miles per year for 5 years (Table 3). With the exception of 1956 and 1958, annual range extension varied between 23.5 and 25.5 square miles. In 1955 a minor movement (Fig. 1) extended the range to its present southwestern limits, while a broad northeastern extension was beginning. The continuing northeasterly expansion is approaching the limits of suitable turkey range. We consider the turkey "established" now on 106 square miles.

Land use and drainage systems have influenced the rate and pattern of range extension. In 1956, cropland and highways apparently held annual range extension to about 17 per cent of the 25.5-square-mile extension of 1955. Our wild turkeys initially occupied the oak–pine forest in the center of the Allegan State Forest, on dry sandy soils of the Plainfield and Coloma–Hillsdale-Bellefontaine associations (Veatch, 1953). Expanding their range beyond the limits of this forest, the turkeys have penetrated surrounding cropland by way of forested drainage systems.

Land-use practices of the Consumers Power Company have helped the wild

TABLE 3.—ANNUAL RANGE EXTENSION (IN SQUARE MILES) OF THE WILD TURKEY IN SOUTHWESTERN MICHIGAN
(Based on Observation of Broods)

Year	Area of Increase[1]	Cumulative Increase	Total "Established" Range
1954	23.5	23.5	49.5
1955	25.5	49.0	75.0
1956	4.3	53.3	79.3
1957	25.0	78.3	104.3
1958	1.5	79.8	105.8
Totals	79.8	—	105.8
Average	16.0	—	—

[1] Original release area was 26 square miles.

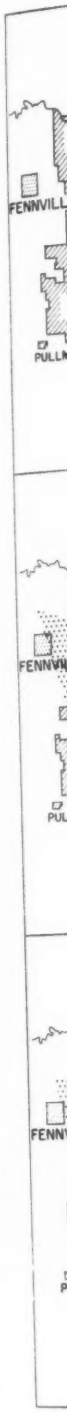

FIG.

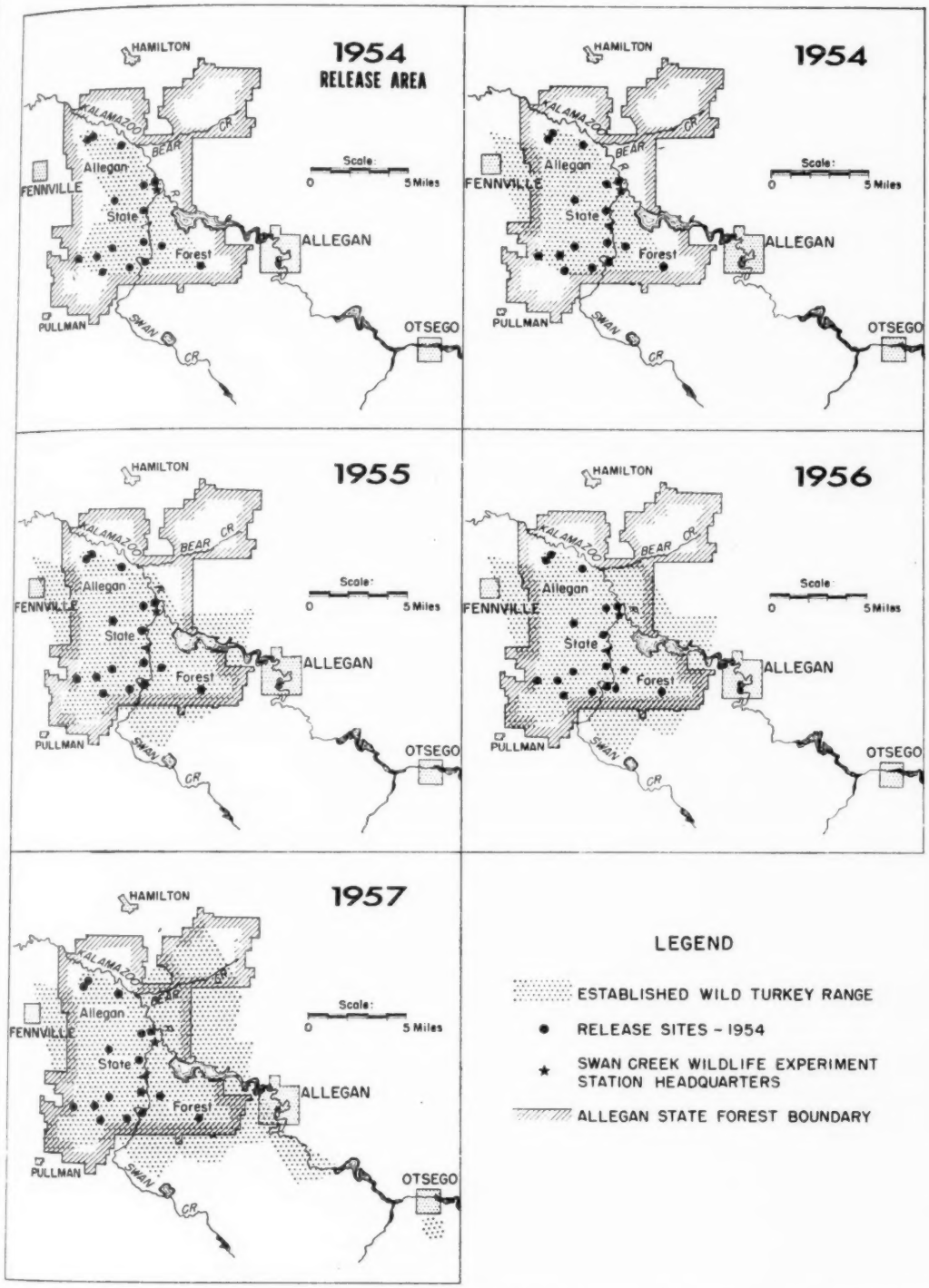

FIG. 1. Wild turkey range extension, 1954 to 1957, in Allegan County, Michigan. The 1958 extension was considered too small to map.

turkey to penetrate cropland, the birds following managed tracts of mature timber and pine plantations southeastward along parts of the Kalamazoo River. This is an example of range extension largely determined by a land pattern of favorable cover in upland areas and on steep slopes bordering the bottom lands. Such patterns result in the interspersion of oak–pine, bottomland hardwoods, and mixed hardwoods. Much of this timber is mature, and when these types occur close to cropland or openings, we have what is probably the best turkey range in the Allegan Forest area.

The wild turkey cannot extend its range much farther in southwestern Michigan, as such an extension will almost certainly proceed along wooded streams to the unfavorable habitat of small farm woodlots.

Our "inhabited" wild turkey range—as indicated by all birds observed and in contrast to the "established" range—now occupies 233 square miles. To obtain this figure, we plotted all observations for 1958 on a map, drew circles of a 2-mile radius around each sighting point, and circumscribed the outermost points. In Virginia, Mosby and Handley (1943) found the average cruising radius of an individual flock to be 2 miles. Our observations indicate a similar flock range.

Our 1958 summer census located 430 birds. We used this peak population level of the year in computing 1.84 birds per square mile. The 1958 winter survey figures, through February 15, showed 0.77 bird per square mile, compared to Missouri's 0.75 bird per square mile (Leopold, 1944) and Virginia's 1.4 birds per square mile (Mosby and Handley, *op. cit.*).

The average winter flock from 1954 to 1958 ranged from 8.6 to 9.8 birds. This gave a winter average, since the release, of 9.2 birds per flock. Bailey, Uhlig, and Breiding (1951) give the average winter flock in West Virginia as 9.9 birds.

WILDNESS

Leopold (*op. cit.*) compares habits of pure wild and hybrid turkey stock. He lists exposed nesting, larger winter flocks, earlier breeding, lower nesting success, and a smaller brood survival as characteristic of hybrid birds. Our birds show some characteristics of both pure wild and hybrid stock.

Recently, general human interference—picnicking, logging, pipeline and powerline construction, berry and mushroom picking, hunting and poaching—appear to have made the birds wilder. The weather during the winter of 1957–58 was a good test of the turkey's establishment. Temperatures down to –17°F., and snow 26 in. deep did not prevent the birds from finding food. We know of no losses due to the adverse weather.

SUMMARY

In 1954, the Michigan Department of Conservation released 202 wild turkeys in the Allegan Forest area. We had selected this area in southwestern Michigan for the release because the habitat was most nearly like that recommended for wild turkey management in Pennsylvania. Survival the first winter was fairly good. The number of broods seen during the summer increased from 21 in 1955 to 32 in 1957. During the summer census of 1958, we located 430 wild turkeys. Winter densities in 1958 averaged 0.8 bird per square mile. Winter flocks averaged 9.2 birds per flock.

Land use and drainage systems have influenced the rate and pattern of range extension. In the "established" range we have observed broods over a 106 square-mile area, but based on all sightings, the birds now inhabit 233 square miles. The wild turkey cannot extend its range much farther in southwestern Michigan. Such an extension would bring the birds into unfavorable farmland habitat.

Apparently, satisfactory survival after the severe winter of 1957–58 was a good test of the turkey's establishment. It appears that this wild turkey population will become static in the near future, when it will reach the limit of suitable range. The flock will continue to serve the primary objective of the release—establishment of the bird for its esthetic, educational, and scientific values.

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IMMEDIATE EFFECTS OF DIELDRIN AND HEPTACHLOR ON BOBWHITES[1]

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The imported fire ant, *Solenopsis saevissima richteri* Forel, was first noted in this country near Mobile, Alabama, about 1920. It spread across the Southeastern States until in 1957 some 26 million acres were inhabited by the ant (George, 1958). Coincident with this spread, research was being carried out by entomologists to discover means of controlling the insect (Eden and Arant, 1949; Blake, Eden, and Hayes, 1959). Little success was experienced, however, until some of the more potent chlorinated hydrocarbon insecticides were tested. It was then found that chlordane at 4 lb. and heptachlor or dieldrin at 2 lb. technical per acre, in granular formulation, would control the ants for periods ranging up to 5 years. Green and Hutchins (1958) reported an economical, short-term control method.

Early in 1957, the possibility of some form of federal program to control or eradicate the ant began to elicit the interests of farmers. By late 1957, an eradication program was underway, and questions were raised as to possible effects of such a program on forms of life other than the ant. These questions were particularly pertinent in this instance because the area inhabited by the ant included some of the finest game habitat in the Southeast. To seek answers to some of these questions an experimental treatment area was established in Wilcox County, Alabama, late in 1957. This area was to be treated with heptachlor and dieldrin by the Plant Pest Control Division of the U.S. Department of Agriculture with the Alabama Department of Agriculture and Industry cooperating. It was the purpose of the research herein reported to learn the immediate effects, if any, of this treatment on the bobwhite (*Colinus virginianus*) population.

Rudd and Genelly (1956) have summarized the literature on the effects of these two compounds on wildlife under experimental and field conditions. No losses associated with the field use of heptachlor were reported at the time of their review, although losses similar to those reported for chlordane were postulated. DeWitt (1956a, 1956b) has reported adverse effects upon reproduction and survival of the young in quail and pheasants from sublethal doses of dieldrin under laboratory conditions.

[1] A contribution of the Alabama Cooperative Wildlife Research Unit, the Alabama Polytechnic Institute, the Alabama Department of Conservation, the Wildlife Management Institute and the U.S. Fish and Wildlife Service, Bureau of Sport Fisheries and Wildlife, co-operating. This study was carried out under a contract-research agreement with the U.S. Fish and Wildlife Service.

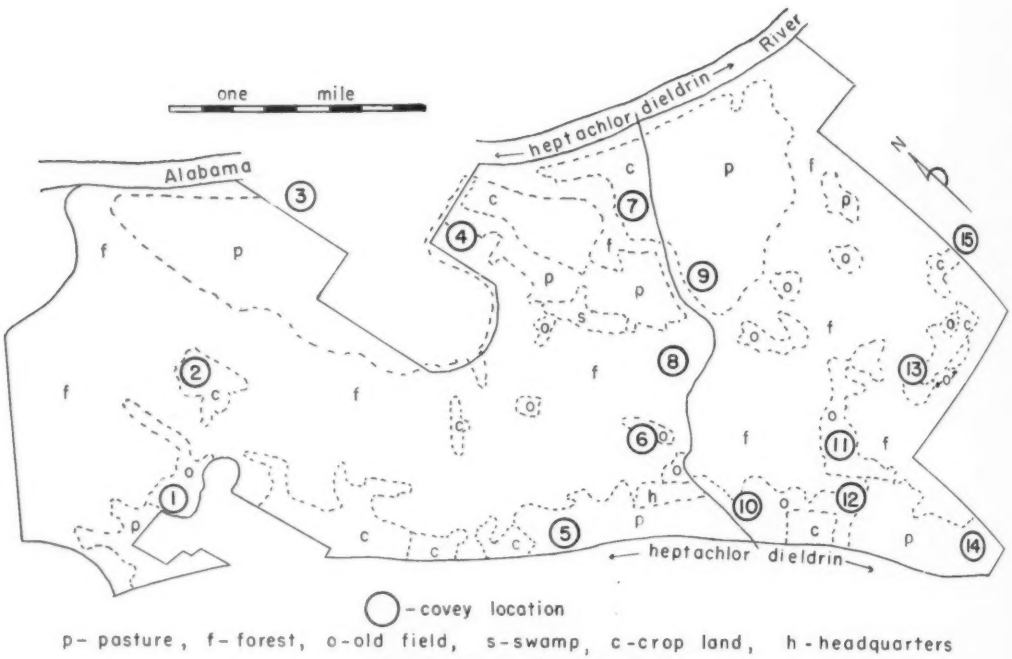

FIG. 1. Map of test area.

Harrington and Bidlingmayer (1958) reported losses of aquatic life in a tidal marsh in Florida following applications of 1 lb. of technical dieldrin per acre.

DESCRIPTION OF THE STUDY AREA

The Lower Coastal Plain Substation of the Alabama Polytechnic Institute Agricultural Experiment Station, together with two adjacent farms, formed the treated area. Forty-one hundred acres of the study area were in one block and, except for 500 acres treated 10 months earlier by the landowner, this block was used as the test area. Because of the drainage pattern of the terrain and the distribution of the quail coveys, the test area was divided unequally. Twelve hundred acres were included in the dieldrin test area, with the remaining 2,400 acres being in the heptachlor test area. Six hundred acres, located 2 miles from the nearest part of the test area, were used as the check.

The test area was composed of Alabama River flood plain and adjacent uplands. Ocklockonee Clay Loam and Leaf Clay Loam were the major lowland soils, while Guin Sandy Loam and Wickham Silt Loam were the dominant upland soils (Swenson, *et al.*, 1938). The flood plain was mostly in excellent pasture, but was poorly drained. Upland cover types were mixed pine–hardwood forest, pasture, cultivated fields, and old fields (Fig. 1). The uplands were well drained and tended to dry out rapidly after rains.

The check area was also adjacent to the Alabama River and was composed of sandy, clay, and silt loams similar to those of the test area. Principal cover types were pasture and cultivated land interspersed with wooded draws and fence rows.

Both the test and check areas represented typical bobwhite habitat for their part of Alabama. Before treatment, the quail population on the check area was somewhat better than on the test area. The woodlands of the test area supported a number of wild turkeys (*Meleagris gallopavo*), and both areas had good populations of songbirds, small mammals, and predators.

METHODS

The insecticides were to be applied at the rate of 20 lb. of granules per acre. Ma-

terials used contained not less than 9.5 per cent nor more than 10.5 per cent of the technical poison (Padget, *in litt.* October 31, 1958; Anon., 1957). Two planes were used in the application—one for each type of insecticide. Treatment was accomplished between March 17 and April 1, 1958.

Samples of the insecticide were caught in rectangular metal pans, each 1.48 sq. ft. in area, placed in arbitrarily selected, level, open sites. Two samples were taken in the upland and two in the bottom land of both the dieldrin- and heptachlor-treated areas. Each sample consisted of 20 subsamples. Each subsample was the material caught in one pan. Pans were placed in two or three rows at right angles to the line of flight of the plane and 5–8 yd. apart in each row. The insecticide from each pan was collected in a preweighed, screw-capped vial. Each sample was weighed on a Mettler electric balance to one ten-thousandths of a gram. Three of the samples were taken in covey ranges, although this was not a factor in the choice of sample sites.

Pretreatment censuses of the test and check areas were conducted between February 6 and March 3, 1958. The censusing was done by intensive search with dogs until each covey was located at least two times. Totals of 94 man-hours and 247 dog-hours were used in this census.

Posttreatment censuses of the two areas were conducted by the same personnel and methods between March 31 and April 15. At that time the birds on the check area were still in coveys, and no appreciable covey breakup occurred until April 21. The posttreatment census required 101 man-hours and 251 dog-hours. Approximately 40 additional man-hours were devoted to searching for dead specimens in covey ranges.

Weather data were obtained from a U.S. Weather Bureau co-operative station on the test area.

TABLE 1.—RAINFALL (IN INCHES) IMMEDIATELY BEFORE AND AFTER PERIODS OF TREATMENT

Date of Application	RAINFALL	
	(5 P.M. Day Before to 5 P.M. Same Day)	(5 P.M. Same Day to 5 P.M. 3 Days Later)
March 17	None	0.83
March 22	None	1.54
March 25	0.23	0.01
March 28	None	0.56
April 1	None	0.40

RESULTS

The samples of the fall that were caught in pans indicated that the application was variable and that the rate may have averaged less than 2 lb. per acre (Fig. 2 and 3). Only one sample of 20 pans resulted in an average catch in excess of 2 lb. per acre. The average pan in the heptachlor area caught material at the rate of 1.03 lb. per acre, and in the dieldrin area at the rate of 1.56 lb. per acre.

Four of the five dates of application were followed in the next 3 days by moderate to heavy rainfall (Table 1). This rainfall pattern, together with a variety of soils, provided a wide range of field conditions.

Fifteen coveys with 139 birds were found in the pretreatment census of the test area

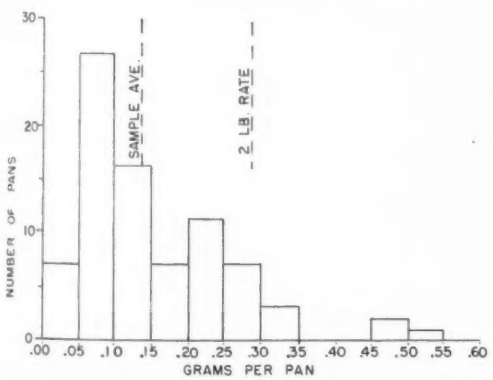

FIG. 2. Histogram of rate of fall of heptachlor collected in 80 samples.

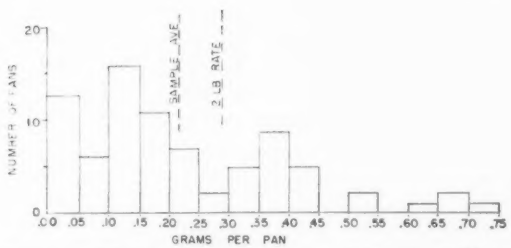

FIG. 3. Histogram of rate of fall of dieldrin collected in 80 samples.

TABLE 2.—RESULTS OF PRE- AND POSTTREATMENT CENSUSES ON TEST AND CHECK AREAS

Area	PRETREATMENT CENSUS		POSTTREATMENT RESULTS		Percentage Loss of Birds
	No. Coveys	No. Birds	No. Coveys	No. Birds	
Heptachlor	8	78	1	10	87
Dieldrin	7	61	1	8	87
Total	15	139	2	18	87
Check	8	76	8	74	3

(Table 2). One of these coveys (No. 3) was never seen on the test area, but was found within 50 yd. of the border. Another (No. 15) was seen on the area only once (Fig. 1). Eight coveys with 76 birds were found on the check area.

Thirteen coveys on the test area disappeared by April 12. In covey ranges treated early in the operation, no live birds were found. Live quail were found only where their range had been treated within 12 days of the census. The last covey range to be treated (No. 10) in the dieldrin area had undergone no loss when first seen after treatment. The record of the disappearance of this covey is as follows:

Pretreatment census ..... covey counted as 10 birds
March 27 ..... counted as 10 birds
April 1 ..... covey range treated with dieldrin
April 3 and 5 .... covey seen as 10 birds
April 10 ..... seen as 5 birds
April 12 ..... seen as 3 sick individuals, 2 found dead
April 14 ..... remains of 2 more found
April 16 ..... remains of 1 more found

No quail were found here again after April 12, even though the area was visited five more times with bird dogs.

The five dead birds found in this range represented the highest percentage of recovery for any particular covey. But one or more dead quail were found in nine different covey ranges. The condition of these birds was as follows: 10 recovered whole; 2 eaten by census dog; and scavenger or predator sign of 9. Seventeen per cent of the quail that disappeared were thus accounted for as dead birds.

Examination of eight of these bobwhites by the Section of Biochemical Investigations, Patuxent Research Refuge, under the supervision of James B. DeWitt, revealed the presence of heptachlor, its epoxide, or dieldrin in their tissues (Table 3).

Censusing on the check area during this posttreatment period showed a loss of two quail, a reduction of 3 per cent in its population compared to the 87 per cent loss on the test area (Table 2).

DISCUSSION

The entire treated area was censused, and marginal coveys were included in the census to preclude confusing them with the per-

TABLE 3.—RESULTS OF CHEMICAL ANALYSES OF QUAIL FOUND DEAD AFTER TREATMENT

Specimen Number	Dry Wt. of Spec. (gm.)	INSECTICIDE FOUND					
		Dieldrin		Heptachlor			
		Total mcg.	mcg./g.	Total mcg.	mcg./g.	Epoxide mcg.	Epoxide mcg./g.
1	22.60	255	11.3				
2	18.87	146	7.7				
3	20.00	118	5.9				
4	25.13	84	3.3				
5	11.40	59	5.2				
6	24.00	128	5.3				
7	26.22					45.00	1.7
8	12.74			4	0.3	45.00	3.5

manent population. As a result, some coveys that ranged partly off the area were found. The quail that survived were in two such coveys, one of which was encountered on the treated area only once, the other not at all. These coveys had not been reduced 18 days after neighboring areas were treated.

For purposes of evaluating the loss of birds that followed the insecticide application, it is advisable to consider two populations, the permanent one and the marginal one. The reduction was 100 per cent for the permanent population, and zero for the marginal. The only evidence that any of the other 13 coveys ventured off the test area is that, out of 10 sightings, covey No. 10 was once seen to cross a paved road into an untreated area.

SUMMARY AND CONCLUSIONS

An experimental area was treated with heptachlor and dieldrin near Camden, Alabama. Samples of the rate of fall of insecticides indicated that the application may have averaged somewhat less than 2 lb. per acre of the technical material, and that the distribution was variable. All resident quail disappeared from the test area. Only two of 76 quail disappeared on the check area. Two marginal coveys survived. One covey was observed during its period of decline and five of the original 10 were recovered dead. Evidence of the death of quail in other coveys was found. Chemical analysis made of quail found dead on the test area revealed the insecticides in their tissues. From these facts, it is concluded that this application of heptachlor and dieldrin resulted in the death of all or nearly all resident quail.

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EDITORIAL NOTES

It is a pleasure to report the Wildlife Society Council's selection of Dr. Charles M. Kirkpatrick (Department of Forestry and Conservation, Purdue University) as the new Editor of THE JOURNAL OF WILDLIFE MANAGEMENT. Dr. Kirkpatrick's appointment takes effect as of our October 1959 issue. Because the preparation of copy for this issue begins intensively on April 1, with copy due at the printer's shop on July 1, Dr. Kirkpatrick's name appears on the inside front cover of THE JOURNAL beginning with this issue, as the man to whom manuscripts intended for publication should be sent.

In May, the American Fisheries Society plans to issue its *Transactions* on a quarterly basis. This important event is awaited with interest throughout our profession, and THE JOURNAL extends to its sister publication the best wishes of The Wildlife Society for a long and illustrious career in its new quarterly existence.

BRIEFER ARTICLES

A COMPARISON OF METHODS FOR ESTIMATING SQUIRREL POPULATIONS[1]

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Methods for estimating wild animal populations are among the most important techniques needed in wildlife research. This paper describes the results of using two census methods (plus a variation of the methods) simultaneously on two small, intensively studied woodlots. Comparison of these results discloses their practicality in censusing squirrels.

This study was conducted over a period of 3 years, 1952–55, in two 10-acre woodlots on the grounds of a hospital on the outskirts of Baltimore, Maryland. These woodlots were stands of large mixed hardwoods, with some individual trees up to 4 feet in diameter, and appeared to be excellent squirrel habitat. Each woodlot was relatively isolated from other woodlots, and movements to and from other forested areas were therefore restricted.

The best applicable method for estimating squirrel populations appeared to be one based on some type of mark and recapture ratio, especially since animals had to be captured and marked for the study of their social behavior and movements (Flyger, 1955).

In addition to trapping squirrels, observations were made on squirrel activity in the woods, permitting counts to be made of the number of animals seen per unit of area. These population estimates, using trap-recapture data and number of animals seen per unit of area, were made at the same time and involved the same squirrels. Comparing the results of these estimates (Table 1) reflects some of the characteristics and limitations of each method.

Population Estimates Based on the Schnabel Method

Squirrels were captured daily for periods of several weeks, permitting use of the Schnabel modification (Schnabel, 1938) of the recapture ratio. This method has an advantage over the Jackson-Petersen method (the so-called "Lincoln Index"), because a series of ratios are averaged. This reduces the chance of an extreme estimate due to sampling error. The formula for this method is

$$\hat{P} = \frac{\Sigma\,(AB)}{\Sigma\,C} \text{ where}$$

$\hat{P}$ = the estimated population;
A = the number captured in one day;
B = the number of animals marked previously that are available to capture on the day of trapping;
C = the number of marked animals caught in one day.

Two types of data were used in this formula: (1) the number of marked and unmarked animals caught in traps and (2) the number of marked and unmarked squirrels seen by the observer in the woods. The two uses of the Schnabel formula are discussed below.

[1] A contribution from the Division of Vertebrate Ecology, School of Hygiene and Public Health, The Johns Hopkins University, and from Pittman-Robertson Wildlife Research Project W-32-R, Maryland Game and Inland Fish Commission.

Table 1.—Comparison of Population Estimates of Squirrels in Two Woodlots Using the Schnabel Formula and the Time-area Method

Woodlot Studied and Date	Population (Schnabel)[1]	Population (Time-area)	Number Seen per 100 15-minute Observations	Number of Observation Periods in which				
				No Squirrels Were Seen	1 Squirrel Was Seen	2 Squirrels Were Seen	3 Squirrels Were Seen	4 Squirrels Were Seen
North Woodlot								
Apr.–May 1954	26	1.41	12.6	78	7	2	0	0
June–July 1954	12	0.20	7.9	95	4	2	0	0
Oct.–Nov. 1954	39 (51)	3.71	60.6	39	12	6	3	1
South Woodlot								
Apr.–May 1954	18	2.16	10.9	90	11	0	0	0
Aug.–Sept. 1954	19	1.45	12.5	71	8	1	0	0
Nov. 1954	28 (48)	4.84	28.6	46	6	2	2	0

[1] The figures in parentheses in this column are the Schnabel estimate based upon sight records, the other estimates in this column being based upon trap recaptures.

Schnabel population estimates based on trap and recapture records.—The use of the Schnabel formula requires that two assumptions be made:

1) The proportion of marked individuals in the sample equals the proportion of marked individuals in the population apart from a binomial sampling error.
2) Losses from or additions to the population do not occur during the time of trapping.

The first assumption is not entirely valid because, toward the end of a trapping period, almost all the squirrels captured had been previously trapped and marked, but a high proportion of unmarked squirrels was always seen while conducting observations on behavior. This indicated a definite tendency toward trap-proneness among certain squirrels. The existence of such a tendency is supported by the observation that there were usually some individuals that could be captured every time the traps were set.

The second assumption is violated in part because a trapping period frequently lasted more than a month and the calculated mortality rate (Flyger, ms.) averaged 10 per cent per month. Furthermore, new squirrels were constantly appearing (at an unknown rate) due to reproduction and immigration. However, since disappearance and recruitment cancel each other to some extent, their over-all effect is probably not more than a 10 to 15 per cent difference in the population estimates.

The use of recapture data in any formula such as the Schnabel or Jackson–Petersen method gives an estimate of the "trappable" animals, which is usually less than the actual population. In addition to this characteristic, the Schnabel method can sometimes give an estimate *lower than the actual number of animals used to make that estimate.* This happens when, toward the end of a trapping period, mostly trap-prone animals are captured. Study of Table 2 shows that, out of 17 estimates made by this method, 10 gave an estimate lower than the minimum number of squirrels definitely known to be alive in the woods. The minimum number of squirrels known to be alive is determined by adding the total number of animals caught to the number of animals marked at an earlier trapping period but not recaptured until a date later than the trapping period in consideration. It is probable that every estimate made by this method was considerably less than the actual population.

The Schnabel formula has been used almost exclusively in fisheries research where the number of animals caught is a small fraction of the actual population (often less than 1 per cent). This characteristic, of being able to give an estimated population less than the actual catch, would not appear when one uses such data representing a small fraction of the population. On the other hand, when a large proportion (40+ per cent) of the population is captured and animals become trap-prone, this property of the formula becomes apparent.

TABLE 2.—ESTIMATED POPULATIONS OF SQUIRRELS—TRAP-RECAPTURE DATA COMPARED TO THE MINIMUM NUMBER KNOWN TO BE ALIVE

Study Area	Date		Estimated Population	Minimum Number Known to be Alive
	Aug.–Sept.	1952	8	11
	Apr.–May	1953	30	18
	July–Aug.	1953	11	19
	Sept.	1953	14	17
NORTH	Nov.	1953	5	9
WOODLOT	Jan.–Feb.	1954	5	10
	Mar.–Apr.	1954	18	12
	June–July	1954	19	16
	Oct.–Nov.	1954	28	29
	Jan.	1955	39	30
	Mar.–Apr.	1955	21	24
	Aug.–Sept.	1952	19	—
	Feb.	1954	17	9
SOUTH	May–Apr.	1954	26	20
WOODLOT	June–July	1954	9	12
	Oct.–Nov.	1954	39	33
	Jan.	1955	17	22
	Mar.–Apr.	1955	18	23

Schnabel population estimate based on trap-sight records.—During the fall of 1954, circumstances permitted using the Schnabel formula with data not subject to the above-mentioned bias caused by trap-prone or trap-shy animals. Such data were available because all the squirrels captured in traps were colored with a dark purple dye, Nyanzol A (Fitzwater, 1943), and the tail hairs were clipped, making it possible to recognize previously trapped animals when these were subsequently seen in the woods. The ratio of these marked and unmarked animals was used in the Schnabel formula to give an estimate of the squirrel population within the woodlots.

Comparison of population estimates made by the two methods (trap-recapture and trap-sight records) shows a considerable difference. This difference appears because estimates based on trap-recapture records pertain to the population subject to trapping, while estimates based on trap-sight records pertain to the animals that can be seen. In this case, the number of animals that can be seen is closer to the actual population than is the number of animals subject to trapping, because there was no reason to suspect that marked squirrels were either more likely or less likely to be observed than were unmarked squirrels. It is therefore believed that, for estimation of squirrel populations, the Schnabel formula using trap-sight records is the best technique available.

POPULATION ESTIMATES BASED ON TIME–AREA COUNTS

Under ideal conditions, it should be possible to estimate the population of a species in a given area based upon the number of animals seen within

smaller sample portions of the area. Such a method has been proposed by Goodrum (1940) for use in estimating squirrel populations. To employ this technique, 10 vantage points were selected in each woodlot. These observation points were visited in sequence, and 15 minutes were spent at each spot before moving on to the next. The number of squirrels seen was recorded, and the distance from the observer to each squirrel was measured. This is essentially the census method suggested by Goodrum. After 50–110 observation periods, the above-recorded data were used to make an estimate of the squirrel population ($\hat{P}$) of a woodlot. Six different estimates were made by this method. The formula employed was

$$\hat{P} = \frac{AZ}{(0.6)\ \Pi\ Sy^2} \text{ where}$$

A = total area of the woods (in each case, 10 acres);
Z = number of squirrels seen;
S = number of 15-minute observation periods;
y = average of all distances from the observer to the squirrels seen.

The constant 0.6 was used because it was believed that only that much of the circle around the observer could be well seen.

The use of the time-area method assumes that the number of animals seen within sample portions of the area can be used to estimate the population of the entire area. The logic behind this method is that sample 15-minute observation periods are used to estimate the number of squirrels that could be seen if it were possible to observe the entire woodlot for one 15-minute period. The greatest disadvantage of this method lies in the fact that the entire population is not active at one time. Furthermore, all the active animals may not be visible to the observer. Inspection of Table 1 indicates that few of the squirrels present in the woods were active (or able to be seen) at any one time. The population estimate based on time-area counts varies from 5 to 22 per cent of the estimate based upon trap-recapture data which in themselves are considered to lead to underestimates of the actual population.

This small trial of time-area counts is perhaps not sufficient for the evaluation of this technique, but there are a number of factors to be considered before employing such a method. First of all, it is necessary to calibrate the method for each individual observer by seasons for one woodland type. If a squirrel population of a white oak woods is to be estimated, it would be necessary to conduct time-area counts simultaneously in another similar white oak woods with a known population. One cannot compare estimates made in winter with those made in the summer, because of the difference in visibility due to leaf conditions of the trees at these seasons. A forest with an open understory cannot be compared with one that has a dense understory, nor can a pine forest be compared with a hardwood forest. The ability to detect squirrels varies greatly between people and must be taken into account. A hazy sun makes looking upward difficult because of the glare, and other weather conditions have their effects on observational ability. After a few hours of observation, the investigator's attention often begins to wander in spite of the best intentions. Therefore, counts made at the beginning of a series of observations might differ from those made at the end of the series. If there is a difference in the amount of activity of the animals at different hours of the day, this must be taken into account.

Consideration of the above factors (and others which are not discussed here because of lack of space) leads to the conclusion that time-area counts are of doubtful practical value in estimating squirrel populations.

The adequacy of the 15-minute observation periods requires consideration. For example, if the squirrels had been frightened by the approach of the observer and had not recovered sufficiently by the end of 15 minutes to venture into sight again, few of them would be found at the beginning of the observation periods. However, as time progressed, and the squirrels gradually overcame their fright, an increasing number of them should be seen. To investigate this possibility, the length of time, in minutes, that had elapsed since the beginning of the observation period until the moment when first seen, was recorded for every squirrel observed (Table 3). Surprisingly enough, there was no difference between the number of squirrels sighted at any of the 1-minute intervals, except that there were more squirrels seen during the first minute period than at any other time. This preponderance of squirrels seen during the first minute might be due to the squirrels having been stirred up by the movement of the observer into the area. There is also the possibility that the squirrels seen

TABLE 3.—THE TIME ELAPSED SINCE THE BEGINNING OF THE OBSERVATION PERIODS AT WHICH SQUIRRELS WERE FIRST SIGHTED

Time from Start (in minutes)	Squirrels Seen
1	15
2	6
3	6
4	6
5	9
6	9
7	9
8	7
9	6
10	8
11	5
12	5
13	7
14	4
15	7
Total	109

during the first minute were those that were active in the immediate vicinity at the time and that those sighted at later intervals were squirrels that were moving into the range of sight. Because a squirrel was recorded only at the first instant that it was seen, any individual active in the area would be recorded only once and that would tend to be at the beginning of the observation periods. From these data it is concluded that, except for the first minute, an observer who remains still and quiet has little effect on the activity of squirrels in the general vicinity.

It must be emphasized that, during this investigation, the relationship of the above methods to the true population was not known. Further research is needed to investigate the relationship that exists between population-estimation methods and the actual population; but for most purposes, an estimate based on trap-sight records appears to be the best available technique.

SUMMARY

Squirrel populations in two 10-acre woodlots were studied at intervals over a period of 3 years. Population estimates were made using the Schnabel formula, employing either of two types of data: trap-recapture data and trap-sight data. The latter type of data gave the most satisfactory results because the method was not subject to bias caused by trap-shy or trap-prone animals. Population estimates based on time-area counts produced unsatisfactory results.

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A NEW PLASTIC TAPE MARKER FOR BIRDS AND MAMMALS

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Plasticized polyvinyl chloride extruded tape has been brought to the attention of biologists by Craighead and Stockstad (1956), who have used the material in color marking various birds and mammals. The material was found to retain its pliability, strength, and bright color under extreme moisture and temperature conditions. These characteristics promise to make the material increasingly popular as a research tool for the use of biologists.

Attachment of markers used by Craighead and Stockstad was by means of the falconer's jesse knot. This method has one disadvantage in that it is usually necessary to insert a finger, pencil, or similar object beneath the marker in order to tighten the knot. This is difficult to achieve when a close fit is desired, as when the marker is being applied to a bird's leg, and it may choke the animal when the marker is being applied to the neck.

To overcome this disadvantage, a method of attachment was devised that requires little pulling to secure the knot. This method involves passing a folded end of the marker through a hole in the opposite end to a point at which a pair of notches in each edge of the tape allows it to unfold and lock in place (Fig. 1). This affords positive size control and greater ease of application. Moreover, it is never necessary to insert a finger or pencil beneath the marker to tighten the knot.

While working at the Welder Wildlife Foundation refuge near Sinton, Texas, from July 1 to September 20, 1957, the senior author leg banded 35 boat-tailed grackles (*Cassidix mexicanus*), 13 black-necked stilts (*Himantopus mexicanus*), and 15 green herons (*Butorides virescens*) with this marker to test its durability. All of these were immature birds as yet unable to fly. At this writing (April 1958), 31 of the 63 birds marked have been reobserved, all after they were able to fly and two or more weeks after they were banded. Only one bird, a black-necked stilt, is known to have lost one of the new-type color markers, and this was probably due to a too-large size being used. Markers were prepared in advance in accordance with published banding schedules. It is known that two of these black-necked stilts lost aluminum bands of the recommended size, presumably because the bands slipped over their feet. The color marker that was lost was probably too large rather than insecurely attached.

During a current Georgia Game and Fish Commission study on Goat Island in the Savannah River near Elberton, Georgia, the junior author recovered nine of 12 gray squirrels (*Sciurus carolinensis*)

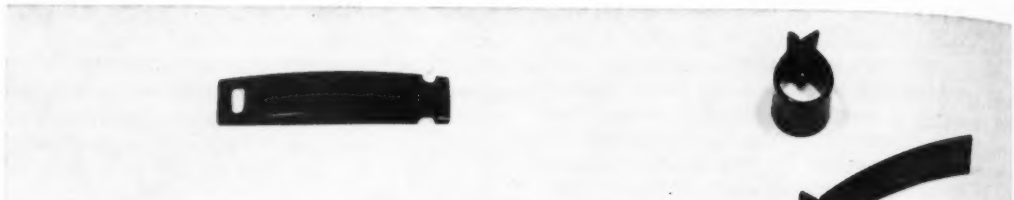

FIG. 1. Plasticized polyvinyl chloride extruded-tape markers before and after tying.

neck banded with this marker. Three squirrels found dead within one week of banding retained their bands, three squirrels retained their bands three months or more, and three squirrels had lost their bands after three months. The size of the band used on gray squirrels was found to be very critical. One collar is known to have been removed by the squirrel by slipping the collar over its head. Another was evidently bitten in two, but it is not known if this was accomplished by its wearer or another squirrel. A collar that was evidently too tight caused a lesion on the neck of one squirrel. No marker is known to have been lost because it was insecurely attached. While sufficient time has not elapsed to judge adequately the durability of this method of attachment, the indications are that it may be as secure as the jesse knot method.

According to a recent communication from the Cee-Bee Manufacturing Co., 76 N. 4th St., Brooklyn 11, N.Y., which produces the marking material used in this study, six widths, #22-0 ½-inch (20 yards per pound), #10-0 ¾-inch (19 yards per pound), #138-0 1-inch (19 yards per pound), #10-0 1½-inch (10 yards per pound), #10-0 2-inch (7 yards per pound), and #196-0 2½-inch (6 yards per pound) are currently being marketed. This material is available in black, white, red, Nile green, Kelly green, royal blue, light blue, navy blue, yellow, pink, lavender, purple, orange, tan, light brown, and dark brown. The #10-0 ⅜-inch material used on boat-tailed grackles, black-necked stilts, and gray squirrels during this study is no longer available. A #5203 Keysort Card Punch obtained from The McBee Co., Athens, Ohio, was used in converting the ½-inch material into markers.

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THE ESTIMATION OF THE FOOD OF FOXES

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Despite the great use made of fecal analyses in studying the food of carnivores, particularly in North America, remarkably little has been done to test the validity of methods of assessment in current use; nor have the correction factors for differential digestion, which are likely to be considerable for some prey species, been worked out. This paper attempts to repair this omission by extending the pioneer work of Scott (1941). Three methods of assessing food from fecal analyses, correction factors for certain prey species, and the amount eaten by captive foxes are discussed.

MATERIALS AND METHODS

Through the kindness of the director of the Edinburgh Zoological Park, three adult foxes (*Vulpes vulpes*), housed in a stone-floored enclosure, were made available for these tests. All

three were in excellent condition and active before, during, and after the tests.

The foxes were first fasted for 2 days and all fecal pellets cleared from the enclosure. During the next 9 days a little over 10 kg. of natural food was given. Two further days were allowed for all pellets to appear, after which the test ended.

The following species were fed to the foxes: 3 rabbits (*Oryctolagus cuniculus*), 80 short-tailed voles (*Microtus agrestis*), 5 bank voles (*Clethrionomys glareolus*), 5 wood mice (*Apodemus sylvaticus*), 4 white laboratory rats, 1 domestic fowl, 1 jackdaw (*Corvus monedula*), 2 domestic pigeons (*Columba* spp.), 1 robin (*Erithacus rubecula*), 3 house sparrows (*Passer domesticus*), 1 skylark (*Alauda arvensis*). Five shrews (*Sorex araneus*) were also offered, but were not eaten. The entire animals were given to the foxes, just as they would be caught in nature.

The pellets were collected daily and wrapped separately in paper. In the laboratory each was thoroughly washed and broken up in a sieve with a 2-mm. perforated base (not a wire mesh), the washings being collected in a white basin. The washings were then examined for the teeth of small rodents. The clean pellet was next floated in the sieve in clean water. This allowed many remains to be identified macroscopically and readily enabled the proportion of each species to be estimated. Where necessary, microscopic examination of hair structure was also made.

The material from each pellet was finally dried, weighed, and stored in separate envelopes with naphthalene. The identified food was entered on a card—one for each pellet.

A separate test was later carried out in which all the food given to these foxes was weighed over a period of about 4 months in order to measure the average daily requirements.

A further test was made in which voles and mice, portions of rabbit, and small birds were fed to a captive fox cub 12 weeks old.

SOURCES OF ERROR IN FECAL ANALYSES

Assessment

Three main methods of assessment are available. These are:

1) *Frequency of occurrence.*—This can either be expressed as a percentage of the total number of fecal pellets or of the total number of occurrences of prey species.

2) *Relative estimated bulk.*—It is not usually practicable to measure the contents of fecal pellets by volume. But it is possible to estimate by eye, the relative proportions of each prey remains if the pellet is suitably washed and floated in clean water. If the contents of each fecal pellet are allotted a percentage, the total of percentages of a given prey expressed as a percentage of the total possible (i.e., number of pellets × 100) is the "percentage relative estimated bulk." This method simply introduces a measure of the amount of each prey in each pellet.

3) *Weight of undigested matter.*—It is usually difficult to separate prey remains in a fecal pellet for accurate weighing. Instead, the relative bulk is estimated as in (2), the dry, cleaned pellet is weighed, and the weights of individual remains calculated.

To be satisfactory, any method of assessment must be constant in its error (if any) over the full range of amount in which a given food can be eaten. By its very nature, "percentage occurrence" is unlikely to achieve this, for at low proportions it will tend to overestimate and at high proportions underestimate. In order to test the consistency of each method of assessment, the feeding test with adult foxes was used in three ways, the complete test and two parts of it; in each, a different proportion by weight of the various prey species had been given. Estimates of these proportions were then made using the three methods of assessment already described; the estimates made from the feeding test with a fox cub are included insofar as they relate to voles (Table 1).

TABLE 1.—A COMPARISON OF THE CONSISTENCY OF THREE METHODS OF ESTIMATING THE PRINCIPAL PREY IN FOUR FEEDING TESTS WITH FOXES

The number of fecal pellets involved in the four tests was: 178 (complete test with adult foxes), 129, 23, and 79 (test with fox cub).

Food	Per Cent of Weight Given	ERROR IN ESTIMATED PERCENTAGE BY		
		Occurrence[1]	Estimated Bulk	Wt. Undigested Matter
Vole	12	+40	+21	+ 7
Vole[3]	17	+13	+12	+13
Vole	19	+19	+17	+17
Vole[2]	68	− 7	+ 1	+ 7
Rabbit	29	− 4	− 1	− 5
Rabbit[3]	45	−12	− 3	− 3
Rabbit	88	−40	−21	− 7
Large bird[3]	29	− 8	−11	− 9
Large bird	50	−20	−16	−11

[1] "Percentage occurrence" here means the frequency of occurrence of prey expressed as a percentage of the occurrence of all prey.

[2] Feeding test with fox cub.

[3] Data from complete test with adult foxes.

Clearly, "percentage occurrence" and "percentage relative estimated bulk" were inconsistent. Sometimes they gave a good estimate, sometimes, as in the case of rabbits, the error was as great as 40 and 21 per cent, respectively. Three feeding tests conducted by Scott (*ibid.*) showed smaller but similar errors; the proportions of bird fed to a fox were 29, 36, and 71 per cent, and the errors in estimation were +1, +7, and −9 per cent. The order in which the food is eaten is likely to affect the estimate, and this may in part account for the very high errors found in estimates of rabbits, since in most of these tests several classes of food were

involved, whereas in those made by Scott only two classes (mouse and bird) were involved. Be that as it may, the two methods of assessment are obviously liable to very large errors and would seem to be suitable for only the crudest analyses.

"Percentage weight of undigested matter," in contrast, shows a reasonable consistency in its error, which enables correction factors (where necessary) to be applied with confidence. This method would therefore seem to be the only worthwhile means of presenting data obtained from fecal analyses.

These conclusions probably apply also to the assessment of the food of raptors (other than owls) from disgorged castings, where an accurate estimate of the number of individual prey items is not possible.

Other Sources of Bias

1) *Method of eating by the predator.*—There can be considerable differences between species in the methods used to tackle prey. For example, in Highland Scotland the wild cat (*Felis sylvestris*) is said sometimes to skin its rabbit prey; the fox does not. In addition, occasional aberrant individuals may eat in an unusual way, but the extent of the habit can usually be discovered by anyone working in the field. Carnivores in general tend to tackle their prey in a particular way. The following observations were made on captive foxes.

Mice and voles were invariably eaten completely, and rats usually, although a tail or a foot was occasionally found discarded. Small birds were sometimes eaten whole but more usually all, or some, of the flight feathers were not eaten. Of the three rabbits given to the foxes, a foot, a jaw-bone, and tufts of fur were not eaten. (In nature, a single fox may not finish a large rabbit in one meal.) Many feathers of the large birds escaped ingestion, and the wings and occasionally a foot were discarded. These findings are similar to those given by Scott (1943).

2) *Proportion of digestible to indigestible matter.*—It is evident that the proportion of digestible to indigestible matter varies greatly between prey species. This, together with the method by which the fox or other carnivores eat, produces errors the extent of which can only be discovered by feeding tests.

CORRECTION FACTORS

Various Prey Species

The correction factors worked out from the data obtained with feeding tests are given in Table 2. The correction factor is that number which, multiplied by the total weight of indigestible matter, will convert the indigestible matter to the total weight of original prey eaten. It should be noted that these correction factors are independent of one another, so that one need not have the combination of prey animals listed in Table 2 in order to be able to apply them.

The comparison between the 12-week-old fox cub and adult foxes shows the same correction factor for voles and mice but a slightly lower factor for small birds. This supports observations on how captive foxes ate their food. Both adults and young ate voles and mice completely and rejected the feathers of small birds to about the same extent. But in the fox cub, the fine feathers of small birds survived digestion better than in adult foxes. In this respect, the fox cub is similar to the pine marten (*Martes martes*) and the weasel (*Mustela nivalis*) (Lockie, unpublished). This captive weasel, however, ate its vole prey in the way that a fox would eat rabbit prey and ate its small bird prey in the way that a fox would a large bird. Correction factors for weasel and fox are therefore likely to be different.

The prey animals listed in Table 2 do not include prey larger than the domestic fowl and rabbit. From my field observations on fox kills it seems reasonable to infer that the correction factor for hares would be similar to that for rabbit. That for lamb and deer fawns would be similar to the factor for large birds, and that for sheep and adult deer in excess of this, owing to the considerable amount of bone, skin, and hair that is not ingested.

Small Rodents

Teeth and fur are the most permanent characters of mice and voles and both survive the alimentary canal of a fox remarkably well. It is time consuming to use fur in order to identify small rodents, and molar teeth have therefore been used. In the tests, about 50 per cent of the pellets with vole fur contained molar teeth.

TABLE 2.—CORRECTION FACTORS FOR VARIOUS PREY SPECIES

Prey	TESTS WITH 3 ADULT FOXES			TESTS WITH ONE 12-WEEK-OLD FOX CUB		
	Wt. Given (gm.)	Wt. Undigested Matter (gm.)	Correction Factor[1]	Wt. Given (gm.)	Wt. Undigested Matter (gm.)	Correction Factor[1]
Voles and mice	1729	75.2	23	522	23.9	22
Rabbit	4541	106.1	43	—	—	—
Rat	775	17.7	44	—	—	—
Large bird	3028	49.8	61	—	—	—
Small bird	126	2.8	45	114	3.1	37

[1] Correction factors are given to the nearest whole number.

TABLE 3.—ESTIMATING THE RELATIVE PROPORTION OF THREE SPECIES OF SMALL RODENT[1]

	TESTS WITH ADULT FOXES			TESTS WITH ONE FOX CUB		
	Microtus	*Cleth.*	*Apodemus*	*Microtus*	*Cleth.*	*Apodemus*
Percentage number fed	90	6	4	38	48	14
Percentage weight fed	89	6	5	40	44	16
Percentage occurrence of molar teeth	89	6	5	27	55	18
Number of molar teeth recovered in droppings expressed as a percentage	90	6	4	34	51	15

[1] Pellets which contain no identifiable rodent teeth are not included.

Table 3 compares the number and weight of *Microtus*, *Clethrionomys*, and *Apodemus* fed to foxes with the frequency of occurrence and number of molar teeth in the resulting fecal pellets (neglecting those pellets that contain no teeth). About 45 per cent of the teeth were recovered in the pellets. The number of teeth recovered in each species, expressed as a percentage of all molar teeth recovered, gives the better estimate of the relative proportion of these rodents eaten.

AMOUNT EATEN PER DAY

In studying predators and their prey it is often necessary, but rarely possible, to estimate what proportion of the prey population the predator has removed in a given period. To calculate this, it is necessary to know—among other things—the amount eaten in a unit of time. This is extremely difficult to calculate for wild and secretive carnivores, but information from captive animals can give a guide.

There are objections to the use of information derived from captive animals: captive animals are less active than wild ones. This is probably true, but the difference is not so obvious to anyone who has visited a zoo after dark. In support of the suggested similarity in food requirements of some wild and captive animals, it might be mentioned that Chitty (1938) estimated the average daily requirements of a captive short-eared owl (*Asio flammeus*) fed on a variety of foods to be between 56 and 168 gm. of vole (*Microtus agrestis*), while Lockie (1955), working entirely on wild short-eared owls established in territories, estimated their consumption to be 90 gm. of vole, a remarkably similar result.

The amount eaten per day by three foxes in the Edinburgh Zoo was weighed from September 9 until March 18, a total of 191 days. The food was given in various amounts, and on one or two days each week the foxes were fasted. In this respect, natural conditions were thus simulated. If, as happened only occasionally, the foxes did not eat all the food given, it was left until they did. It was impracticable to weigh the foxes before and after the test. However, they were not noticeably fatter or thinner at the end of the test.

The food given was 85 per cent horse flesh, 14 per cent rats, mice, and rabbits, and 1 per cent bread and milk. Since the horse flesh, as given, had no fur and bone, 8 per cent of the total weight of horse meat was added to make this food more similar to natural prey. In 191 days, three foxes ate 7,670 oz. of food. This makes the daily requirements of each fox about 13.3 oz. (378 gm.). This figure compares favorably with Scott's estimate of about 1 lb. per day (Scott, 1941).

ACKNOWLEDGMENTS

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SUMMARY

Three methods for assessing the food of foxes from fecal analyses were tested. "Frequency of occurrence" was found to have serious errors, the extent of which depended both on the amount of a given food eaten and probably on the order in which it was eaten. "Estimated bulk" also had considerable errors. The "weight of dry undigested matter" in fecal pellets gave an estimate consistent in its error. Correction factors for the differential digestion of various prey species were calculated. These indicate that estimates of rabbit, rat, and small bird need only slight correction, while estimates of vole and large bird require considerable correction. The relative proportions of three common rodents eaten by the foxes were estimated fairly accurately by expressing the number of molar teeth recovered for each species as a percentage of all molar teeth recovered. The amount eaten by captive foxes during 191 days gave an average daily intake of 378 gm.

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DENTAL PATTERNS AS AGE INDICATORS IN MUSKRATS[1]

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This paper describes a technique enabling one to obtain age-ratio data on muskrats (*Ondatra zibethicus*) trapped during March and April. Several different aging techniques have been developed for separating adult muskrats from young of the year. Among the criteria used for separation are: size and appearance of the internal reproductive organs (Errington, 1939); appearance of the external genitalia (Baumgartner and Bellrose, 1943); pelt-primeness pattern (Applegate and Predmore, 1947; Shanks, 1948); length of cased pelt and weight (Lay, 1945); zygomatic breadth (Alexander, 1951); and upper-incisor width (Sooter, 1946).

All of these methods are more or less accurate during the fall and early winter (Schofield, 1955). However, during spring trapping seasons, young of the preceding year have matured to a point where there is so much overlap between the two age groups that none of these methods are sufficiently accurate to obtain reliable age-ratio data.

Sather (1954) outlined a method by which he was able to separate the two age groups by dental pattern, basing his work on a study by Gould and Kreeger (1948) of skulls of the Louisiana muskrat. This technique involves the degree of extrusion below the bone line of the anteriormost buccal fluting on the first upper molar. In his collection of 58 known-age muskrat skulls from Nebraska, Sather (*op. cit.*) found that in adults, none of which were less than 18 months old, the end of the fluting was extruded well below the bone line. In the subadults, which were between 4 and 9 months old, the fluting ran deep into the alveolar socket, and the end was not visible.

Up to the time when a muskrat's molar teeth first attain full length, at 2 to 3 months of age according to Galbreath (1954), there are no grossly evident roots. With age, the occlusal surface of the crown becomes worn and roots develop, the latter pushing the crown farther away from the alveolar socket. The roots continue this process at such a rate that extrusion and wear of the occlusal surfaces are approximately equal. In the older adults examined, I found that from 75 to 90 per cent of the total tooth height was contained in the length of the roots themselves. Since the fluting is an integral part of the crown and is therefore extruded with it, its relative position to some fixed reference point, such as the bone line, indicates the amount of growth and wear that has taken place; this can then be correlated with age.

I used Sather's method on a series of skulls from muskrats harvested during the March and April 1956 trapping period at Delta, Manitoba. At this time, subadults were between 7 and 11 months old; the older of these were of an age not represented in Sather's sample. The typical patterns of the older adults and the younger subadults were readily distinguishable, but there remained a large group of in-between cases. As a result, Sather's criteria, per se, could not be used to obtain accurate age ratios.

An attempt was then made to modify this method with respect to the dental patterns that prevailed during the spring at Delta. The entire sample of 681 cleaned skulls was sorted to determine the dental patterns that were most commonly encountered. The skulls from 12 muskrats tagged as nestlings the previous summer verified the relationship of each of the major patterns with age. For purposes of this paper only, animals less than 1 year old have been divided into two categories: subadults—muskrats born early in the preceding breeding season and averaging approximately 10 months of age; and juveniles—animals born later in the preceding breeding season and averaging about 7 months of age.

The three most frequent patterns observed and the age class with which they were associated (Fig. 1) were as follows: (1) highly developed roots and end of fluting extruded well below the bone line—adults; (2) moderate root development and end of the fluting just barely or not quite emerged from the bone line—subadults; and (3) little or no root development and fluting ending deep in the alveolar socket—juveniles. The 618 specimens that clearly fell into each of these three groups were separated. The remaining 63, 9 per cent of the total, exhibited questionable dental patterns and were classed as probable adults, juvenile-subadults, or unknown.

Following separation into these categories, the upper right molar was removed from each skull. Each tooth was then measured to determine the distance from the occlusal surface to the end of the fluting. Measurements were taken to one-hundredth of a millimeter using an ocular micrometer mounted on a binocular dissecting microscope. Using only

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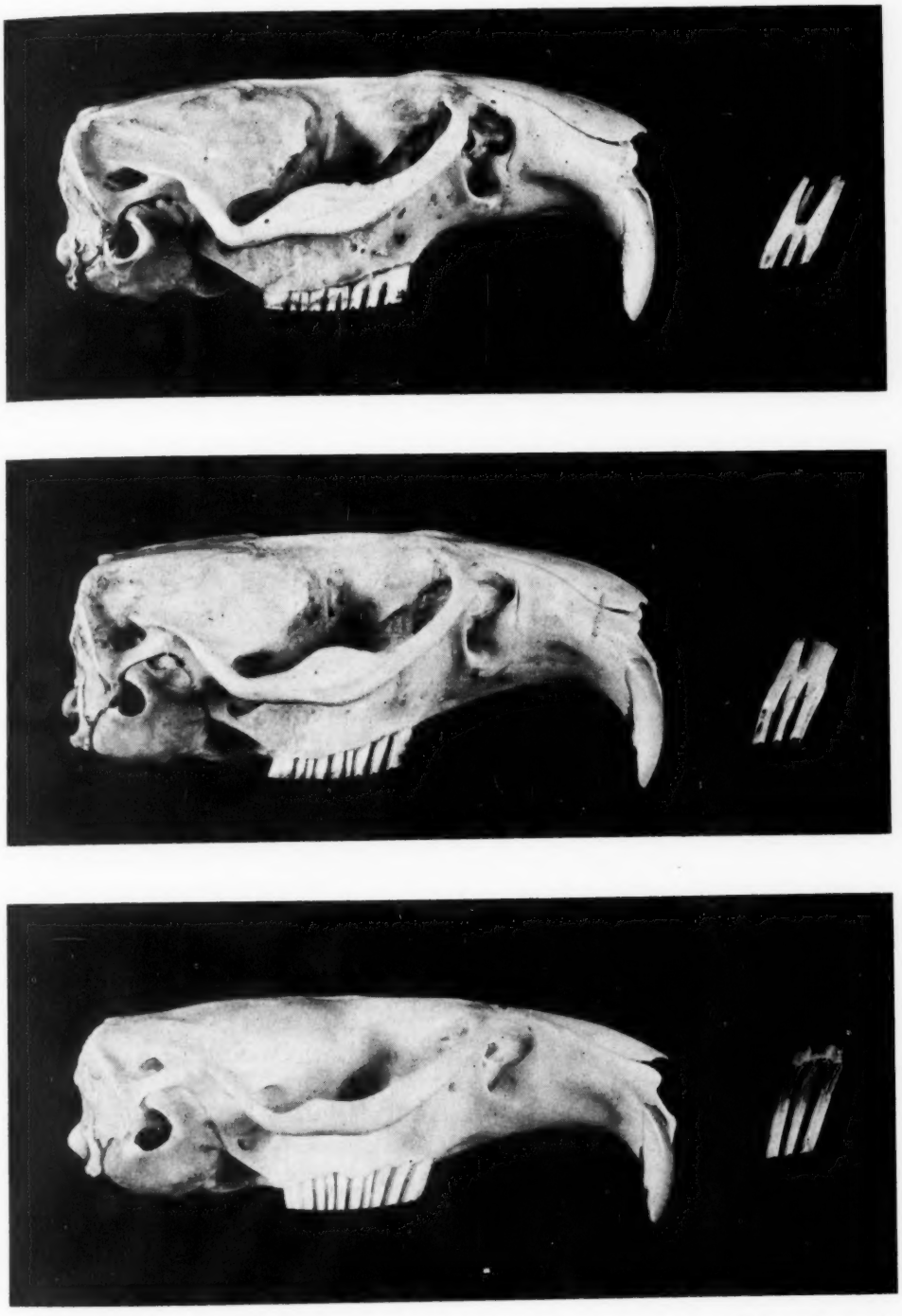

FIG. 1. Dental patterns in a series of spring-trapped muskrats. Note the relation of the end of the fluting to the bone line on the first molar and also the progressive elongation of the roots and wearing down of the crown with age. *Top.*—Typical adult; roots well developed; end of fluting extruded well below bone line. *Center.*—Typical subadult; moderate root development; end of fluting at point of emergence from bone line. *Bottom.*—Typical juvenile; very little root development; fluting extends deep into alveolar socket.

TABLE 1.—COMPARISON OF AGE CATEGORIES FOR 681 MUSKRAT SKULLS BY EACH OF TWO METHODS

Age Class	*In Situ* Ocular Examination		Measurement of Fluting Length	
	No.	Per Cent	No.	Per Cent
Definite				
Adult	58	9	77	11
Subadult	131	19	197	29
Juvenile	429	63	407	60
Questionable				
Probable adult	24	4	—	—
Subadult-juvenile	17	2	—	—
Unknown	22	3	—	—
Adult:Young	1:7.0		1:7.8	

the fluting-length measurements from the 618 specimens that clearly fitted into one of the three major age classes, the average length and standard deviation for each category was determined; then, on the basis of derived 95 per cent confidence limits, the separation points between age classes were established. Finally, the 63 questionable cases were assigned to the age class indicated. The ratio of adults to young was 11 per cent higher by the method of ocular examination of the tooth *in situ* than was found by measuring the fluting length of the extracted tooth (Table 1). This difference, however, does not significantly alter the data, and the purposes of most investigations would hardly warrant the great expenditure of time required to measure fluting lengths.

When the frequency distribution of fluting lengths was graphed by one-tenth millimeter increments, a trimodal curve resulted (Fig. 2). There was surprisingly little overlap between the age groups. Of the skulls that, by ocular examination, were originally assigned to one of the three major age classes, measurement of fluting length indicated that 2 subadults were misjudged to be adults, 3 adults were called subadults, 1 juvenile was classed as a subadult, and 27 subadults were thought to be juveniles. Of the 63 specimens showing questionable dental patterns, 12 of the probable adults were adults while 12 were subadults; 13 of the subadult-juveniles were subadults while 4 were juveniles; and 6 of the unknowns were adults whereas 16 were subadults.

The age ratio derived from this series of skulls does not reflect the actual pretrapping-season ratio of adults to young in the 1955–56 population at Delta, and should not be used alone to calculate survival information. The skulls used in this study were entirely from animals trapped in March and April 1956, whereas nearly 2,000 muskrats had previously been harvested during the November 1955 trapping period. Since adults are trapped in greater proportion to their actual occurrence in a population when an area is first trapped (Errington, pers. comm.), the pretrapping-season adult:young ratio would be considerably higher than the 1:7.8 ratio presented here.

After some experience has been gained, this technique can be performed quite rapidly. Although best adapted to skinned carcasses, it can be employed on unskinned animals. With a sturdy scalpel or small knife, the flesh around the first upper molar is scraped down to the bone. The relation of the end of the fluting to the bone line may then be easily observed; if the fluting extends up under the bone line it is usually advisable to chip the bone away until the end can be seen.

Muskrat managers often cannot secure an adequate sample of harvested animals for aging because of other commitments of their time during the trapping period, the time and expense involved in traveling around to contact the trappers frequently, and other similar reasons. Being able to obtain age-ratio data by examining only the skull may help to solve this problem. The investigator can request the trappers to decapitate the skinned carcasses and save the skulls. These can then be collected at intervals during or following the season, when they can be worked over and aged at a convenient time.

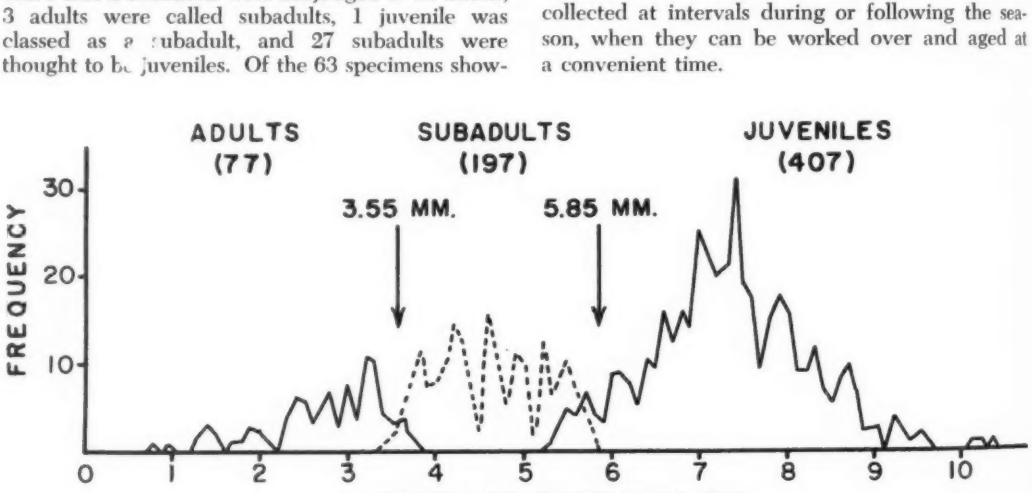

FIG. 2. Frequency distribution of tooth fluting lengths.

I believe that aging muskrats by *in situ* observation of dental patterns can be utilized in many areas where it is necessary to collect age-ratio data during the spring. Since this method enables one to separate different age classes of young muskrats, it can be used to determine the relative contributions to the harvest of early- and late-born young as well as the usual adult:subadult composition. It would be advisable to have some known-age skulls with which to check the correlation between dental pattern and age, since there may be some variation in different geographic areas from the patterns presented here.

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FEEDING AND GROWTH OF A CAPTIVE MOOSE CALF

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The wildlife biologist often has to care for captive wild animals as an unexpected addition to his general duties. Little information is available concerning the care of most wild mammals. For this reason, notes on the general feeding care and growth of a captive moose calf (*Alces alces*) are recorded here.

Since 1952, five moose calves have been kept in captivity at the Cormack Wildlife Division office of the Newfoundland Department of Mines and Resources. Three were successfully reared to the yearling stage, while twin male calves died from bacterial infections during weaning. Notes and growth rates were recorded for the last calf, raised in 1957 by the author.

On June 28, 1957, a female moose calf, judged at the time to be approximately 2 weeks of age, was obtained from a woods camp near Birchy Lake in central Newfoundland. The animal was first sighted by woodsmen on June 22 and was taken to the camp on June 25. I believe that the cow had been killed.

Between June 25 and June 28, the animal was fed small quantities of evaporated milk by the woodsmen. It was in a weakened condition when the author began feeding and care on June 28. Its weight on that date was 31 lb.

The initial milk diet provided consisted of 1 qt. of half-strength evaporated milk with one-half teaspoon of salt added, fed three times each day. Her milk intake gradually increased after the first week in captivity, reaching a maximum of almost 2 gal. each day just prior to weaning. After weaning, she gradually reduced her milk intake, consuming only what was wanted from a large bucket. The animal was completely weaned by August 15 at the age of 9 weeks. This was accomplished by partial feeding from a bucket and requiring the animal to suck the handler's fingers placed in the milk, then gradually drawing the fingers away.

After weaning, the calf's water consumption, which had been a maximum of 2 qt. per day from a bottle, increased to almost 2 gal. per day.

Calf ration was first placed in the animal's trough on August 12 when the moose was 8½ weeks of age. She fed on the dry mash at once, consuming approximately 4 gal. per day. The ration (Protena) contained 16 per cent protein, 2.5 per cent fat, and 10 per cent fibre. No liquid was added.

Browse of four species—mountain maple (*Acer spicatum*), birch (*Betula papyrifera*), cherry (*Prunus pensylvanica*), and willow (*Salix* spp.)—was cut and hung about the pen from the first day in captivity at Cormack. The animal fed sparingly upon the leaves of mountain maple only, for the first few days, but shortly thereafter began feeding

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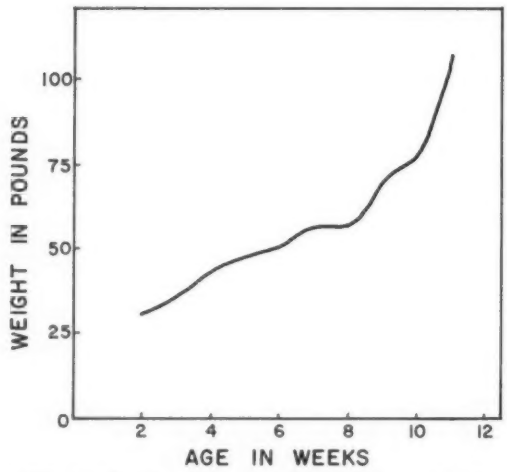

FIG. 1. Growth rate of a captive female moose calf.

upon the leaves of the remaining three species. Mountain maple was always the first species to be eaten. No records of the actual volume of browse taken daily were kept. Twelve to 15 stems of fresh browse were provided twice each day.

To weigh the moose, a set of tackle blocks was used to lift the animal in a canvas belly sling. The sling was then suspended from a 200-lb. spring scale. Weight increases are recorded in Table 1.

At the age of 8 weeks, the calf began gaining weight rapidly. This increase in rate of gain coincided closely with the initial feeding of calf ration, the weaning of the animal, and the increase in water consumption. The moose was still growing at an accelerated rate on August 30, when it was approximately 11 weeks old, and when weighing was discontinued because of its removal to St. John's.

TABLE 1.—WEIGHTS OF A CAPTIVE FEMALE MOOSE CALF

Date	Approx. Age in Weeks	Weight in Lbs.	Weight Gain in Lbs.	Chest Girth in Mm.	Belly Girth in Mm.
June 28	2	31			
July 5	3	35	4		
July 12	4	43	8		
July 19	5	47	4		
July 26	6	50	3		
Aug. 2	7	56	6		
Aug. 9	8	56	0	816	787
Aug. 16	9	69	13		813
Aug. 23	10	77	8	889	928
Aug. 30	11	106	29		940

A comparison of growth rates between this eastern moose and a Wyoming moose described by R. H. Denniston (1956. Zoologica, 41(3):105–118) shows the eastern moose gaining 75 lb. (from 31 to 106 lb.) in 9 weeks, against the Wyoming moose's gain of 89 lb. (from 39 to 128 lb.) in a similar period.

The moose described in this paper is now being cared for in the Bowring Park Zoo, St. John's, Newfoundland, where it appears to be in excellent condition.

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A MACROSCOPIC OVARY-SECTIONING METHOD

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In the past 10 years, mammalian ovaries have been receiving increasing attention by wildlife researchers as a supplemental source of information on the reproductive performance of a number of species. The study of whale ovaries by Wheeler (1934) indicated that corpora lutea scars could be used as indicators of the reproductive history and age of individual animals. Cheatum (1949) described a macroscopic technique for determining ovulation incidence from the occurrence of corpora lutea scars in the ovaries of white-tailed deer (*Odocoileus virginianus*). This paper stimulated other researchers on ungulates to investigate the ovary (Robinette, *et al.*, 1955; Halazon and Buechner, 1956; and Golley, 1957).

Cheatum (*op. cit.*) suggested slicing the ovaries into 1-mm. sections with a sharp razor blade or scalpel. This type of hand-slicing has the disadvantage of producing relatively rough and uneven sections that are often difficult to use for histological studies.

Our paper reports on a method of embedding and sectioning ovaries so that uniform sections of any required thickness, down to 1 mm., can be obtained. These sections are ideally suited both for macroscopic examination and for the preparation of histological sections of specific ovarian structures. The technique is adapted from a gross brain-sectioning technique that was described by Garrett (1953) for demonstration purposes and later modified in the Department of Anatomy of the University of Wisconsin (Settlage, *et al.*, 1958) for research work.

The fact that the technique has been successfully used for tissues as diverse as brain and ovary gives

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some indication of its versatility. We agree with Settlage, *et al.* (*ibid.*), who suggested that it can be adapted to a wide variety of uses in biological research, especially where a combination of macroscopic and microscopic studies of tissues is undertaken.

PREPARATION OF THE EMBEDDING MATERIAL

The embedding material is a mixture of corn meal and gelatin in the proportion of 3 gm. of corn meal to 2.5 gm. of sheet or powdered gelatin to 12 cc. of water. A mix of approximately 100 times this size, that is, 300 to 250 to 1,200, makes a good experimental batch, enough to embed at least one pan of ovaries, as will be described.

The embedding material can be prepared by autoclaving (Settlage, *et al.*, *ibid.*) or as follows: Soak the corn meal for at least 4 or 5 hours in half the amount of water to be used; dissolve the gelatin over heat in the remainder of the water; combine the two, and cook in a double boiler for at least 3 to 4 hours. If the gelatin is cooked for longer periods, so that the water content has been reduced, water should be added to retain the viscosity of freshly cooked mix.

EMBEDDING AND SECTIONING MOOSE OVARIES

Since the use of the technique from this point will vary considerably, depending on the size of the ovaries that are being sliced, a description will be given of the way we have used it to section the ovaries of moose (*Alces alces*).

To embed the ovaries, a layer of the mix ½ to 1 in. thick was poured into an aluminum cake pan 10 in. by 4 in. by 3 in. This was then solidified at room temperature or in the cooling tray of a refrigerator. A second thin layer, just thick enough to hold the ovaries in place, was then poured on and the ovaries were embedded in it as soon as it began to solidify. The final covering layer was poured on when the ovaries were firmly set in the second layer.

The ovaries were placed in the pan in rows of four. Each pan held from 10 to 14 pairs. To avoid errors, the specimen number was written on each ovary with India ink, and a plan was prepared showing the exact location of the ovaries in the pan. When the block was solid, the ovary numbers were written with India ink on the surface of the block over their exact location in the block. This was the permanent reference number for each pair of ovaries as long as it remained in the mix. The blocks were removed from the pans by a light heat treatment applied to the sides and bottom of the pan.

Prior to slicing, the blocks were placed in 10 per cent Formalin for approximately 48 hours. This hardening greatly reduces the stickiness of the block and the subsequent fouling of the slicer blade.

The blocks were sliced on a commercial meat slicer. It is helpful to wipe the cutting edge of the blade every eight or ten slices with a cloth wet with water and detergent. The large sliced blocks were cut into smaller ones each of which contained one pair of ovaries. These sliced blocks were trimmed and tied in cheesecloth. Bags made from old nylon hose are even more suitable, as the numbers on the blocks are easily read through the nylon.

The sliced blocks were stored in quart preserving jars in 10 per cent Formalin. Some were reworked after a 3-year period and were as easy to handle as when they were originally prepared.

In selecting material for microscopic study, we simply removed the desired portion of the ovary from the slice and placed a small India ink dot on the face of the ovary that was to be embedded uppermost in the paraffin block. The labels, and later the slides, were marked, as for example, C-90-53(2)-3B, meaning that the ovaries were from Moose C-90, collected in 1953, and that the histological sections were to be cut from face B of Slice No. 3 of Ovary No. 2. It was then simple to correlate a histological section with the gross region of the ovary.

ADVANTAGES FOR MACROSCOPIC STUDY OF OVARIES

The smooth uniformly cut sections permit rapid appraisal of the presence of various structures in the ovaries. By retaining them in the blocks, the slices remain in order, so that the observer can work back and forth comparing structures or making measurements with no confusion or possibility of misplaced slices.

Although it may appear that considerable work is involved in sectioning ovaries by this method, we have found that, once one is familiar with the steps, a large series of ovaries can be handled in less time than by the conventional hand-slicing method. An added advantage is that the method is particularly well suited for use where a technician is available to handle the preparation of the material.

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FETAL RECOVERIES IN MULE DEER

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This report summarizes incidental information on fetuses recovered from pregnant mule deer (*Odocoileus h. hemionus*) on the National Bison Range, Moiese, Montana.

Fetus-doe ratio.—The mean number of fetuses per pregnant doe, as I determined it in 1955–56, did not differ significantly from that determined for the same herd by Sears (1955) in 1953–54 (Table 1). The ratio of 1.66 is based on all age classes combined, although Sears (*ibid.*) found the highest reproduction rate in the National Bison Range herd to be in the 4- to 5-year-old age classes, and the lowest rate in the 1- to 2-year-old age classes. The over-all Utah data (Robinette and Gashwiler, 1950) yielded a ratio of 1.61 and the Interstate Deer Herd (Chattin, 1948) had a ratio of 1.75. The composition of any deer herd in respect to its age classes is a factor in determining the fetus per pregnant doe ratio.

Sex determination.—The identification of sex by external characteristics in fetuses is rather difficult and uncertain in specimens that have an F–R length less than 70 mm. or that are not more than approximately 60 days of age. The appearance of the genital tubercle was noted at roughly 46–48 days (C–R, 28–32 mm.), and two genital swellings lateral to the tubercle were noted at approximately 49–50 days (F–R, 36–38 mm.). At about 60 days of age (F–R, 70 mm.), sex possibly might be determined by the position of the phallus with respect to the nipples and the anus.

Twin-size.—An examination of 17 sets of opposite-sex twins revealed no significant tendency for either sex to dominate in weight or F–R length in my material. Difference in weight of individual sets of twins was quite pronounced in a few cases, whereas the F–R lengths in the same samples differed only slightly.

Pregnancy rate.—The percentage of does pregnant in the Sears (*op. cit.*) series, based on 64 animals over 1 year in age, was 91 per cent. The pregnancy percentage of the other series used is based on animals collected in December and later. Fifty out of sixty does, or 83 per cent of this other series, were pregnant. This gives a combined pregnancy percentage of 87. Robinette and Gashwiler (*op. cit.*) found 85 per cent of the Utah sampling, excluding fawns, to be pregnant.

Sex ratio of fetuses over 70 mm.—Fetuses were selected that were at least 70 mm. in F–R length and gave a sex ratio of (47:41) 100 females to 87 males. However, if the 96 deer fetuses with identifiable sex characters were compared, a sex ratio of (48:48) 100 females to 100 males was found. Among the 31 singletons analyzed, there were 12 females and 19 males.

The body weight of 89 fetuses between 50 and 90 days of age, inclusive, gave an average body weight of 47 gm. for females and 45 gm. for males. In the total available sample between 50 and 90 days of age the average body weight of 34 singleton deer fetuses was 32 gm., and of 68 twins 41 gm. However, when comparisons were made of grouped animals by 10-day intervals, there was no significant difference in body weight between males and females, and between singletons and twins during the first 100 days of intrauterine life.

Acknowledgments

Grateful acknowledgment is made to the U.S. Fish and Wildlife Service, Montana Fish and Game

Table 1.—Comparative Productivity of Selected Deer Herds

Herd Studied	Interstate Deer Herd	Utah	National Bison Range, Montana			
			Sears	Others	Total	Per Cent of Total Fetuses
No. pregnant	48	246	64	50	114	
Per cent of pregnant females with						
1 fawn	29	43	42	36	40	24
2 fawns	67	56	55	58	56	68
3 fawns	4	1	2	6	4	6
4 fawns	—	—	2[1]	—	1	2
Mean no. of fetuses per pregnant doe	1.75	1.58	1.6	1.7	1.66	
Reference	Chattin (1948)	Robinette and Gashwiler (1950)	Sears (1955)	This study		

[1] This single occurrence of quadruplets has been previously reported by Sears and Browman (1955).

Department, Montana Cooperative Wildlife Research Unit, and to Ludvig G. Browman, Montana State University.

SUMMARY

Over 87 per cent of the female mule deer collected during the breeding season on the National Bison Range were pregnant, with a fetus-doe ratio of 1.7. Roughly 60 per cent of the does had more than one fetus, while 24 per cent of all fetuses recovered were singletons. Identification of sex by external characters can be made when fetuses have attained the age of 60 days, or 70 mm. in F–R length. The sex ratio of fetuses 70 mm. or over was 100 females to 87 males.

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THE USE OF RADIO–TV BY STATE WILDLIFE CONSERVATION DEPARTMENTS

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The purpose of this study was to determine how wildlife conservation departments in each state were using radio and television in connection with their public information programs in January 1958. Of the 48 states (Alaska had not yet been admitted to the Union), 46 answered all or most of the questions. Three of these states indicated that radio and TV were not being used in their information programs.

Basically, the study was concerned with (1) the size of and average salaries paid by those public information sections that made use of radio and/or TV, (2) the professional personality of the information specialists, (3) the types of program materials they produced, and (4) the extent to which they used the broadcast media.

STAFF AND SALARIES

Those states that used radio–TV in their wildlife conservation information programs employed from 1 to 19 persons, resulting in a national average of 5.6. Average salaries in these department sections ranged from $3,900 to $6,500 per year, with a mean of $4,975.

Although we expected to learn otherwise, there was no consistent relationship between the number of persons employed in the public information sections of the departments, their salaries, and the geographical location of the wildlife agency (Table 1). Salaries and number of employees varied as widely between states within a given region as they did between states of different regions.

Since the amount of wildlife resources varies between states, the salaries and their size paid by these information sections were compared to the number of fishing-hunting licenses issued in each state. For instance, one east-north-central state issued more licenses (2,370,000) than any other state for the year ending June 30, 1956 (U.S. Census Bureau, 1957). At the time of our survey (January 1958), there were more persons employed in this state's wildlife conservation information section (19) than in any other state. It also had one of the highest average annual salaries ($6,000) in the nation. One of the south-central states, however, issued about one-fourth as many licenses (621,000) (U.S. Census Bureau, *ibid.*) for the same period, reported the lowest average salary of any of the reporting states, but employed 11 persons in public information—sixth highest number in the nation. Average salaries in other states that issued approximately the same number of licenses (500,000–750,000) during the same period ranged from a low of $3,900 to a high of $6,000, with a mean of $4,972. These same states averaged 7.8 employees, although the

TABLE 1.—RANGES IN SALARIES AND NUMBER OF EMPLOYEES IN PUBLIC-INFORMATION SECTIONS WHICH USED RADIO AND TELEVISION (BY REGION)

Region[1]	Average Annual Salary	Number Employed
New England	$4500–5940	1–4
Mid-Atlantic	———[2]	5–6
East north central	4800–6000	3–19
West north central	4200–5520	2–8
South Atlantic	4200–6000	1–12
East south central	4800–5400	4–5
West south central	3900–5500	5–12
Mountain	4500–6500	2–16
Pacific	5100–5700	4–6

[1] Based on divisions established by U.S. Census Bureau, *op. cit.*, p.xvi.

[2] Insufficient data.

individual sections ranged from 4 to 16 employees.

More persons hunted and/or fished in the five east-north-central states than in any other geographic region in fiscal 1956 (U.S. Census Bureau, *ibid.*). These states averaged 10 persons (in public information) whose salaries averaged $5,600. About half as many persons hunted and/or fished in the four west-south-central states, but their information sections averaged 9.3 persons who were paid an average salary of $5,100.

Of two New England states, one issued 159,000 licenses to fishermen and hunters by mid-1956 (U.S. Census Bureau, *ibid.*), employed one person who worked in public information, and paid him $5,940. The other issued 35,000 more licenses, employed one person who earned $4,500—$1,500 less per year.

From these selected data, one broad conclusion is evident. Salary structure and number of employees in a given state's wildlife conservation information section depend not so much upon geographic location or amount of public activity as they do upon factors not measured by this study. One may speculate, however, that differences in section size and salary are dependent upon (1) budgetary co-operation of the various state legislatures, (2) assignment of available funds to the various divisions of each department, which is a reflection of administrators' policies and attitudes in individual agencies, and (3) the particular value placed upon the person(s) who staff a given state's public information section.

EDUCATION AND BACKGROUND

With regard to the professional personality of the persons who work with radio–TV as part of the over-all public-relations program, about 1 in 2 had either majored in wildlife management in college or had practical experience in the field, or both. Three out of four gained their knowledge of the broadcast media through practical experience.

While most states reported various combinations of backgrounds represented in their public-information sections, practical experience in both wildlife management and radio–TV was indicated more often than any other single category. Almost three times as many states employed college wildlife majors in their information programs as those who had majored in broadcasting. (It should be pointed out here that the number of states shown in Table 2 *et seq.* do not total 48, since most states checked more than one category.)

TABLE 2.—PROFESSIONAL BACKGROUNDS REPRESENTED IN WILDLIFE PUBLIC-INFORMATION SECTIONS (BY NUMBER OF STATES[1])

Background	In Wildlife Mgmt.	In Radio–TV
Practical experience	12	28
College major	17	6
College minor	0	3
College courses	8	9
Vocational school	1	2

[1] Data based on 38 states.

TABLE 3.—TYPE OF BACKGROUND "MOST DESIRABLE" IN A NEW EMPLOYEE HIRED TO WORK WITH RADIO-TV (BY NUMBER OF STATES[1])

Background	In Wildlife Mgmt.	In Radio–TV
Practical experience	13	28
College major	21	8
College minor	6	6
College courses	5	14
Vocational school	0	3

[1] Data based on 38 states.

Each state was asked to indicate what combination of background and training would be "most desirable" if it were to hire a new person to work in the public-information field (Table 3). Replies indicated that the person who had majored in wildlife management was regarded as being more desirable than the person who had been limited to practical experience in that field. The implication is that a prospective employee would do well to have formal preparation in wildlife management before seeking employment, at least in the field of wildlife conservation information.

One of the original hypotheses in this study was that the best combination of background for a prospective public-information employee would be a wildlife management major and a radio–TV minor. Most states did not agree. Over half consistently regarded practical experience as being more desirable, and nearly 30 per cent regarded courses in broadcasting (less than that which would be required for a college minor) as being sufficient background for a prospective employee.

MATERIALS USED

The next consideration concerned the kind of materials the information section produced for radio and television. Of the 43 states that reported using radio–TV, 20.6 hours per week were, on the average, devoted to preparation of programs, although the range in the various states was from 1 to 120 man-hours per week. Five basic types of program materials were established by the survey (Table 4).

Note that two-thirds of the states reported using films for television. While filmed program material

TABLE 4.—PROGRAM MATERIALS PRODUCED FOR RADIO–TV (BY NUMBER OF STATES[1])

Type of Material	Radio	TV
Interviews	33	32
Films	—	32
Talks	25	25
Public-service announcements	23	20
News releases	7	5
Panel discussions	0	2
Drama	1	0

[1] Based on 43 states.

TABLE 5.—PROGRAM MATERIALS MOST FREQUENTLY PRODUCED (BY NUMBER OF STATES[1])

Type of Material	Radio	TV
Interviews	29	20
Films	—	24
Public-service announcements	10	7
Talks	9	5
News releases	2	1
Panel discussions	0	1

[1] Based on 41 states.

is more likely to interest a larger audience than the more pedestrian "talk" or "interview," especially on TV, it should be made clear that these films were not necessarily complete package-programs. There was considerable evidence indicating the preparation of film "clips" of from 1- to 10-minutes' duration designed for use within a program. Also, half of the states that reported using film further indicated that they helped to distribute films prepared by commercial firms, such as arms and ammunition companies, oil companies, and others. What percentage of these states also prepared their own footage, of whatever length, in addition to that supplied by outside firms was not ascertained. Further investigation into this particular area should prove interesting and worthwhile.

Table 5 indicates a preference for interview programs over talks, and further shows the relative frequency with which the various kinds of materials are produced. The apparent preference for the interview format may be due to any of several factors: (1) Interviews require less preparation on behalf of the producer than the unilateral talk for the same amount of material communicated; (2) interviews are generally regarded as more "listenable" due to change of voices and/or faces; and (3) information specialists may be limited in their own knowledge and find it easier to bring an "expert" to the studio and lead him with questions rather than try to convince the same person that he should make a solo performance, unaided.

RADIO VS. TV

Television participation by wildlife-information sections was only about one-third that of radio in terms of the number of state departments using the media. Based on the national average, these sections participated in 1.2 programs per week that were 16.7 minutes in length and were telecast by 4.5 stations. On the other hand, they participated in 3.5 radio programs that were 12.8 minutes in length and broadcast by 23 individual stations.

Because of the nature of the medium, television requires more time (and personnel) to produce a program than a similar program on radio. Station program time in some states (which might otherwise be sold to a sponsor) was reportedly "at a premium." One state further indicated that "competition for good time is keen."

In general, what kind of co-operation were information sections given by the radio–TV broadcasters? According to the majority of states, station co-operation was "good," i.e., 32 states indicated that radio stations either "actively solicited materials" from them or at least "used all materials offered." Twenty-seven states indicated the same kind of co-operation from television broadcasters.

FUTURE OF RADIO–TV

By midsummer 1958, 97 per cent of U.S. households had at least one radio set; 85 per cent had television (Neilsen, 1958). In the average American home equipped with radio–TV, almost 2 hours a day were spent listening to the radio, and nearly 6 hours a day were spent watching television (Neilsen, *ibid.*). It seems clear that the audience for the wildlife-information specialist is now available as never before. What of the future of radio and TV as tools for communicating wildlife-conservation information? Thirty-four states saw an increase in their use of radio and TV in the future. Six states (the remaining 8 failed to answer the question) intended no future expansion because they believed they already were doing as much as they could, or that they lacked sufficient funds and/or personnel.

Thus, we may conclude that radio and television are being widely used by state wildlife-conservation departments and that the outlook for future use is bright. These departments, which by no means limit their information-education activities to the broadcast/telecast media, apparently recognize the potential of these mass-communication devices, even though the ratio of television to radio program production seems to lag behind what we are able to learn of the nation's television to radio program consumption.

Based on present use and intention, wildlife-conservation departments in the U.S. appear to regard radio and television as worthwhile means by which public understanding and co-operation may be enlisted in wildlife-conservation programs.

SUMMARY

The study sought to measure how radio–TV were being used by state wildlife-conservation departments in terms of the salaries and size of public-information staffs, education and background of information staff employees, type and extent of program production, and a comparison of their use of radio and television.

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APPLICABILITY OF THE ASCOLI TEST TO EPIZOOTIC TULAREMIA IN WILD RODENTS

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The Ascoli thermoprecipitin test for diagnosis of tularemia has been applied to experimentally infected animals including voles (*Microtus*) and found to be useful in identifying the infection (Larson, 1951). Sarchi (1930) reported successful use of the method for diagnosis of tularemia in water rats (*Arvicola*) in Russia, but no reports have appeared in this country on practical application of the test to diagnosis of disease in wild animals. A great increase in voles in several western states and the occurrence of tularemia among them (Jellison *et al.*, 1958) afforded an opportunity for application of the test to field specimens.

Materials and Methods

Specimens were taken from carcasses of voles (*M. montanus*) found near Klamath Falls, Oregon, from December 1957 to March 1958. The animals were divided into two groups based upon the relative occurrence of tularemia in enzootic or epizootic proportion in the areas from which the specimens were taken. Areas were classified as enzootic if only occasional specimens were found infected with *Pasteurella tularensis* and the majority of animals found dead had succumbed to other agents, e.g., poison. An epizootic area was one in which *P. tularensis* was isolated from the majority of carcasses. Organs tested were liver, spleen, lungs, heart, and kidneys. Liver was most frequently tested. The state of preservation of carcasses varied from fresh to partial mummification or disintegration. In some instances the state of preservation was not noted. Tissues were stored either frozen or in glycerine mixed with an equal amount of 1/60 M Sorenson's Buffer at *p*H 7.4 and kept cool (1–10°C) for periods of 1 to 4 weeks. They were then ground in saline, and aliquots of each suspension were injected subcutaneously into six adult Swiss mice. Those that died or became ill were necropsied, and streaks were made from spleen and heart blood onto blood agar plates with and without cystine.

Tissue antigens and antiserums for the Ascoli test were prepared by the procedure previously described (Larson, *op. cit.*). Ten per cent suspensions of tissue in saline were made on a weight/volume basis. In order to determine if comparable results could be obtained from preparations that had been heated before or after grinding, a test (suggested by Gatlin Brandon, Director of Laboratories, Oregon State Department of Health) was performed on tissues from experimentally infected Swiss white mice that had been treated both ways.

Experimental Results

Forty-three voles from enzootic areas and 46 from epizootic areas, all found dead, were included in the study. Results of tests are tabulated (Table 1) for comparison but cannot readily be subjected to statistical evaluation because of the small numbers in individual categories and because the combined categories are composed of heterogeneous samples. The heterogeneity will be discussed further.

Among the 39 putrescent carcasses, 8 (21 per cent) were negative by both tests and 22 (56 per cent) were positive by both. Only 3 (8 per cent) yielded cultures of *P. tularensis*, yet failed to react in the precipitin test, while 6 (15 per cent) failed to yield cultures of the organism although positive precipitin tests were recorded. Thus, 77 per cent of the animals gave consonant results with the two tests. It is evident that animals dying early in the

Table 1.—Comparison of Results of Injection of Tissues and of Ascoli Tests for Detection of Infection with *P. tularensis*

State of Preservation	Results		Areas		Per Cent of Agreement	
	Injection	Ascoli Test	Enzootic	Epizootic		
Putrescent (39)	+	+	3	19	56	77
	−	−	7	1	21	
	+	−	1	2	8	23
	−	+	2	4	15	
Totals			13	26	100	
Fresh (29)	+	+	6	8	48	76
	−	−	7	1	28	
	+	−	4	2	21	24
	−	+	1	0	3	
Totals			18	11	100	
Unknown (21)	+	+	1	7	38	71
	−	−	6	1	33	
	+	−	0	1	5	29
	−	+	5	0	24	
Totals			12	9	100	

course of infection may not contain a sufficiently large number of organisms to react with antiserum, and it would appear that 3 of the animals fall into this group. The six animals reacting only to the Ascoli test suggests that, although antigen was retained in the tissue, the organisms were either nonviable or so overgrown with other microbial species as to make it impossible to isolate *P. tularensis*.

Among 29 fresh carcasses of voles examined, 14 (48 per cent) were positive in both tests, and 8 (28 per cent) were negative in both. Six voles (21 per cent) yielded cultures but were negative in the Ascoli test. Only 1 (3 per cent) of the animals gave positive precipitin reactions in the absence of positive cultures. Seventy-six per cent of the animals yielded results that were in agreement. In 44 cases both tests were positive, and in 23 both were negative, while in 22 one method only was positive.

Animals were infected experimentally, and comparison was made of titers in Ascoli tests on their tissues heated either before or after extraction with saline. The variations noted are within the limits of reproducibility of the test (Table 2).

The virulence of isolates of *P. tularensis* from all sources in the area is of interest because it was relatively low and uniform. Isolates were obtained from enzootic and epizootic vole infections in the winter of 1957–58 from water taken from streams and ditches and from ticks. All were virulent for Swiss mice, voles, and guinea pigs, i.e., 1 to 10 viable bacteria constituted a lethal dose. However, the virulence for domestic rabbits was low since a million or more organisms were required to produce progressive infection. This is in contrast to the usual virulence of isolates from sheep and from wild rabbits, the smallest doses of which usually kill domestic rabbits as well as guinea pigs and mice (Bell *et al.*, 1955).

DISCUSSION

The Ascoli thermoprecipitin test for tularemia has been used in studies of zoonoses in the USSR (Sarchi, *op. cit.*; Khatenever, 1943) and for quick positive diagnosis of the disease in man in this country (Larson, *op. cit.*). In Russian work, evaluation of the test was based upon results compared with those of stained smears and cultures.

TABLE 2.—COMPARISON OF TITERS OF ANTIGEN WHEN TISSUES ARE HEATED BEFORE OR AFTER EXTRACTION

Specimen No.	Titer	
	Heated before	Heated after
1	80	80
2	80	160
3	160	80
4	320	320
5	160	80
6	160	160

Khatenever found one or more tests positive in 87 animals. Organisms were seen in smears from 77 of these, isolated in culture in 46, and Ascoli tests were positive in 73. Sarchi obtained positive thermoprecipitin reactions with tissues of 31 naturally infected and 2 experimentally infected water rats but not with uninfected tissues.

It is impossible to make unequivocal identifications of *P. tularensis* in smears. Gross lesions afforded indication of infection in some carcasses, but these instances were the exception. Therefore, only the precipitin test and isolation procedures were applied routinely. A total of 89 voles found dead were studied by the combined procedures, and 66 gave positive results when tested for *P. tularensis* by isolation or the Ascoli test. *P. tularensis* was isolated from 54 voles, and the Ascoli test was positive in 56 instances. Unfortunately, no absolute criterion of death from tularemia was applicable to all of the specimens, and therefore the fallible data obtained by each method are discussed below.

Isolation of *P. tularensis* from a carcass is presumptive evidence of tularemia as the cause of death. However, presence of only a few organisms is sufficient to initiate infection in white mice, whereas a concentration of approximately 50 million per ml. is necessary for a positive precipitin test (Larson). A low concentration of organisms may be found in carcasses of infected animals that died from some other causes, or in badly decomposed carcasses in which only a few viable organisms survive. As autolysis progresses, isolation becomes less certain, whereas autolysis has no influence upon the results of the Ascoli test (Larson). The high incidence of tularemia in some areas and concurrence of other lethal agents suggested that occasional deaths would occur from other causes. The Ascoli test, which is positive only with high concentration of antigen, is probably more reliable than isolation as an indicator of advanced disease.

The Ascoli thermoprecipitin test is a procedure that provides evidence of tularemia in carcasses of animals. It is particularly useful when large numbers of specimens in various stages of decomposition must be examined. It is more convenient, quicker, and less expensive than isolation procedures. Safety is also greater, especially if tissues are heated before trituration. Sarchi has successfully applied the test to tissues preserved in Formalin and in glycerine, and we have confirmed his results (W. Wicht and J. F. Bell, unpublished data).

Other diagnostic tests, including isolation procedures, are also fallible and subject to interpretation.

SUMMARY

The Ascoli thermoprecipitin test and isolation procedures for *P. tularensis* were applied to tissues of 89 voles found dead in the field. In about 75 per cent of the instances, results of the two tests were either both positive or both negative. The

safety of the former procedure is much greater for investigators. The value of the thermoprecipitin test in the study of tularemia in nature is discussed.

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WILDLIFE DAMAGE TO CROPS IN THE UNITED STATES

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To make an appraisal of crop damage due to wildlife depredations, a questionnaire was sent to all state game agencies in 1957. All replied. The answers to this questionnaire provided the data for this paper. The authors wish to thank those employees of the state game agencies whose co-operation in completing "one more questionnaire" made this report possible.

FINDINGS

Grain fields and orchards were rated as being most subjected to wildlife damage (Table 1).

The most destructive species, or groups of species, were reported to be deer, waterfowl, cottontails, and beaver (Table 2). Rats, mice, predatory birds, and predatory mammals were only infrequently mentioned.

Only six states indicated that deer were no problem: Delaware, Georgia, Iowa, Missouri, Oklahoma, and Rhode Island. Respondents from ten others (Alabama, Connecticut, Indiana, Mississippi, Nevada, North Carolina, Ohio, South Carolina, Tennessee, and Virginia) indicated that damage by deer was either slight or was restricted to local areas. The majority of respondents reported that they had found no effective control of deer other

TABLE 1.—CROPS DAMAGED BY WILDLIFE IN THE UNITED STATES
(listed in descending order of importance)

Crops	Ratings by States									Total
	1	2	3	4	5	6	7	8	?	
Grains	16	10	4	4	4	1	–	–	4	43
Orchards	11	11	7	4	2	–	–	–	2	37
Vegetables	6	8	8	4	4	2	–	1	2	35
Tree plantations	1	3	5	4	5	4	2	–	1	25
Improved pastures	5	4	3	3	2	3	2	–	1	23
Ornamentals	1	3	1	8	–	5	2	–	1	21
Hays	3	1	1	1	–	1	–	–	–	7
Berries and fruits	1	2	2	–	–	–	–	1	–	6

[1] Present address: University of Alaska Extension Service, College, Alaska.

TABLE 2.—WILDLIFE SPECIES CAUSING CROP DAMAGE IN THE UNITED STATES

Category	Species	No. of States
GAME MAMMALS	Deer (*Odocoileus hemonius* and *O. virginianus*)	40
	Cottontails (*Sylvilagus*)	15
	Elk (*Cervus canadensis*)	7
	Bear (*Ursus americanus*)	6
	Antelope (*Antilocapra americana*)	5
	Tree Squirrels (*Sciurus*)	5
	Moose (*Alces americana*); javelina (*Pecari angulatus*)	1 (each)
GAME BIRDS	Waterfowl	18
	Pheasant (*Phasianus colchicus*)	11
	Band-tailed pigeon (*Columba fasciata*); California quail (*Lophortyx californica*); ruffed grouse (*Bonasa umbellus*); chukar (*Alectoris graeca*)	1 (each)
NONGAME MAMMALS		
Furbearers	Beaver (*Castor canadensis*)	15
	Raccoon (*Procyon lotor*)	5
	Muskrat (*Ondatra zibethicus*)	4
	Nutria (*Myocastor coypus*)	1
Others	Woodchuck (*Marmota monax*); prairie dog (*Cynomys*); gophers (*Thomomys* and *Geomys*)	10
NONGAME BIRDS	Grackles (*Cassidix* and *Quiscalus*) and blackbirds (*Euphagus* and *Agelaius*)	11
	Crow (*Corvus brachyrhynchos*)	4

TABLE 3.—STATES PAYING CASH FOR CROP DAMAGE CAUSED BY GAME SPECIES[1]

State	Source of Funds	Remarks
Colorado	state game agency	game only
Massachusetts	state game agency	deer only
New Hampshire	state game agency	game only
Pennsylvania	state game agency	bear only
Utah	state game agency	big game and upland birds
Vermont	state game agency	deer and bear
Virginia	county funds (in some counties)	deer and bear
Washington	state game agency	game animals
Wisconsin	legislative appropriation	deer and bear
Wyoming	state game agency	game only

[1] "Bear damage" payments probably include those made to compensate for loss of stock, apiaries, etc., as well as crops.

than shooting. Others specified that, within limits, fencing or paneling was an effective measure. Answers from Colorado, Indiana, Maine, Massachusetts, Montana, North Carolina, and North Dakota indicated varying degrees of success with chemical repellents. Noisemakers were rated according to varying degrees of success by respondents from Colorado, New Mexico, North Carolina, and Wyoming.

Ten states are currently making regular payments for damage caused by game (Table 3).

TABLE 4.—VARIOUS METHODS USED BY STATE GAME AGENCIES TO MINIMIZE OR PREVENT CROP DAMAGE

Method	No. of States
Special shooting permits issued to landowners	28
Trapping by state game agency personnel	28
Noisemakers	23
Fencing and/or paneling	13
Chemical repellents	11
Shooting by state game agency personnel	11
Unrestricted shooting by landowners	5
Herding	3
Planting of "diversionary" crops	3
Extension-type trapper education	1
Special trapping permits issued to landowners	1

Steps to alleviate damage by game species are currently being taken by all state game agencies except Arkansas, Delaware, Missouri, and Ohio. Aside from the manipulation of seasons and bag limits, which we believe almost all states consider to be a means of minimizing crop damage, 11 different methods are used to minimize or to prevent such damage (Table 4).

Fifteen state game agencies reported that they had research under way on the problem of crop damage: Arizona, California, Colorado, Idaho, Illinois, Louisiana, Michigan, Minnesota, New Hampshire, New York, North Dakota, Pennsylvania, Washington, Wisconsin, and Wyoming.

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A METHOD FOR MEASURING MORTALITY OF COTTONTAIL RABBITS IN WINTER

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This paper describes a self-checking method of determining winter population loss in the cottontail rabbit (*Sylvilagus floridanus*). It involves pre- and postwinter trapping, the marking of each sample with a different dye, a drive census following each trapping period to record numbers of marked and unmarked rabbits, and finally several calculations of the Lincoln Index type based on these records.

The use of dye to mark the tails of captured and released cottontail rabbits seems to be widely used in population studies, although it appears to be mentioned in the literature only by Dell (1951–52). Fitzwater (1943) mentions the successful application of picric acid to the white fur of ground squirrels and the successful dyeing of even the colored fur of other mammals, including rabbits, with Nyanzol-A. Dell (*op. cit.*), in a popular article, describes a method of estimating rabbit populations by trapping members of the population, dyeing their tails with either picric acid (yellow) or Rhodamine B extra (red), releasing them, and later walking strips to flush as many rabbits as possible. The two dyes were used to distinguish rabbits from adjacent areas. The data obtained were used in the Lincoln Index to calculate the population estimate.

The method described by Dell is essentially similar to that followed in most recent studies of rabbit populations. This method eliminates the effect of trap proneness, which is experienced when box traps instead of sight records are used to take the second sample. Two such trap-dye-drive censuses, one before winter and another after winter, should give an estimate of the mortality that occurred in the interim, providing immigration and emigration are negligible or balanced.

The method applied in this study directly estimates the mortality that occurred during the winter,

by the simple expedient of dyeing the rabbits' tails a different color during the late-winter trapping period. The retention of the dye from the first trapping period (although faded somewhat) made it possible to determine, by a drive census after late-winter trapping, the ratio of rabbits dyed in fall to rabbits dyed in late winter. A knowledge of the actual number of rabbits marked in the fall and in the late winter permitted calculation of the number of fall-marked rabbits missing (and presumably dead) during the late-winter census drive. If one assumes no differential mortality between marked and unmarked rabbits, the winter mortality can be determined. The probability of dying derived from the differential dyeing of tails was used to check the probability of dying derived from the difference between the fall and spring censuses.

PROCEDURE

These two methods have been used on two study areas in central Illinois. One area, 100 acres in size, leased to the 4-H Clubs of Illinois, is planted to various species of deciduous and evergreen trees, which are separated into 2-acre blocks by mowed paths. On this area a systematic drive is easily carried out. The other area, also 100 acres in size, is a wildlife sanctuary with undisturbed vegetation. The lack of landmarks on the sanctuary to guide a crew made drives less efficient than on the planted area. The methods were applied for 2 years on the 4-H area with good agreement between the methods; on the sanctuary, the methods were applied for only 1 year and did not agree.

The rabbits were trapped in box traps of various types. The tails of the rabbits were dyed with a saturated solution of picric acid in 95 per cent ethyl alcohol during the fall trapping period. During the trapping period in late winter, the tails of the newly caught rabbits were dyed with Nyanzol-A (Nyanza Color and Chemical Co., 109–111 Worth St., New York 13, N.Y.) in a solution of water and 35 per cent alcohol. The picric acid dyed the tails a bright yellow that faded to a pale yellow by February. The Nyanzol-A, a dark purple dye, appeared black from a distance.

Following each trapping period, a systematic drive was carried out on the areas by eight to twelve members of the Section of Wildlife Research, Illinois Natural History Survey, and two retriever dogs. Two observers were stationed on an open area at the end of each strip to be censused, and two observers watched the flanks of the advancing line of drivers. During the drive, observers and drivers kept a record of the number of marked and unmarked rabbits seen.

FINDINGS

On the 4-H area, 86 rabbits were trapped, dyed with picric acid, and released from September 18 to October 28 of 1956. When the drive was performed on November 8, 97 rabbits were seen, 25 of which had dyed tails. Calculations by the Lincoln Index indicated 333 rabbits, with a standard error of 56.3 (Davis, 1956:19), in the fall population for 1956. From January 21 to February 4 of 1957, 14 rabbits were trapped, marked, and released. Eight of the 14 were recaptures from the fall trapping period; their tails were redyed a bright yellow, easily distinguishable from the pale yellow tails of those rabbits marked during the previous fall. Six of the 14 were new captures, the tails of which were dyed red with a dye that is no longer available (Basic red, American Cyanamid Co., Dyes Department, Bound Brook, N.J.). The drive on February 5 resulted in sight records on 27 rabbits, of which 4 had bright yellow tails, 4 had red tails, 5 had pale yellow tails, and 14 had white (unmarked) tails. Rabbits with bright yellow tails or red tails were considered to have been rabbits marked in early February, and rabbits with pale yellow tails or white tails were counted as rabbits not captured in February. Calculations by the Lincoln Index method indicated a total late-winter population of 47 (S.E.=14.0) rabbits. Thus, based on the difference between the two censuses, there was a winter mortality of 286 or a probability of dying of 286/333, or 0.86.

To calculate the winter mortality on the basis of the ratio of rabbits with red tails (6) to those with yellow tails (86) in the February drive, the ratio (6 to 86 or 1 to 14.3) was noted as if there were no mortality among the yellow tails during the winter. The actual observed ratio of red (4) to yellow tails (9) (both bright yellow and pale yellow grouped) in the February drive was 1 to 2.25. The difference of 12.05 yellow tails is assumed to be due to the mortality of yellow tails that occurred during the winter. The equation $\frac{N}{86} = \frac{12.05}{14.30}$ will give the number of yellow tails that died, or $N = 72.4$. Then the winter probability of dying is calculated to be 72.4/86, or 0.84.

The use of the above methods provided an estimate of 259 (S.E.=79.0) rabbits in the fall of 1957. The corresponding late-winter estimate was 31 (S.E.=5.6) rabbits. The difference between these fall and late-winter populations is 228, and represents a probability of dying of 0.88 for the winter of 1957–58. The probability of dying as calculated from the ratio of yellow tails (13) to dark purple tails (7) (Nyanzol-A) seen in the late-winter census drive was 0.89.

On the sanctuary area the fall estimate was 238 (S.E.=69.7) rabbits, and the late-winter estimate was 60 (S.E.=15.0) rabbits. The mortality for the winter of 1957–58, as derived from these census figures, was 178 rabbits, representing a probability of dying of 0.75. However, when checked by the ratio of dark purple tails (3) to yellow tails (5) seen during the late-winter drive, the probability of dying was calculated to be only 0.31. I believe that either the fall or late-winter census drive was

inefficient. Probably the late-winter drive was at fault because of insufficient man power, compounded by the greater difficulty in driving this area.

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SUMMARY

A method for measuring the winter mortality of cottontail rabbits is described. The method is based on dyeing the rabbits' tails different colors during fall and late-winter trapping periods and determining the color ratio by a census drive. The reliability of the method is simultaneously checked by Lincoln Index estimates of the fall and spring populations, based on census drives to determine the ratio of dyed to undyed tails observed. Examples of the method applied to two 100-acre study areas are given. On one area the method was applied for 2 years with good agreement between the method and the Lincoln Index estimates for both years. On the second area agreement between the method and the Lincoln Index estimates was poor, probably due to a poor census drive.

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SOME EFFECTS OF SODIUM PENTOBARBITAL ANESTHESIA ON JUVENILE BLACK BEARS

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Recent studies of the black bear (*Ursus americanus*) in Michigan (Erickson, A. W. 1957. Techniques for live-trapping and handling black bears. Trans. N. Amer. Wildl. Conf., 22:520–543) have afforded an opportunity to determine some effects of sodium pentobarbital on this species.

At the Cusino Wildlife Experiment Station near Shingleton, Michigan, we administered sodium pentobarbital intraperitoneally to three male and one female juvenile bears weighing from 24 to 32 lb. The dosage was 1 cc. (1 grain) per 5 lb. of body weight. Temperatures were taken rectally.

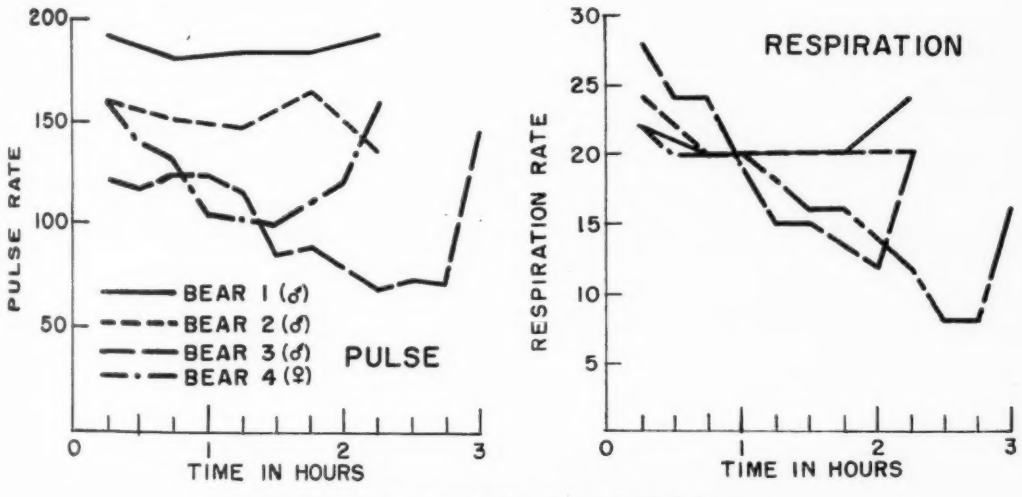

FIG. 1. Pulse and respiration of juvenile black bears.

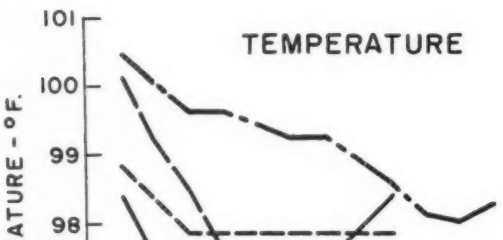

FIG. 2. Temperature of juvenile black bears.

Pulse was determined with a stethoscope. The first determinations were made 15 minutes after the animals had been anesthetized; subsequent readings were made until just before recovery.

The initial response of the animals to anesthesia showed a gradual depression of pulse, respiration, and temperature for all bears (Figs. 1 and 2). Variation occurred between bears in the period immediately preceding recovery. The respiration rate of bears Nos. 1, 3, and 4 showed a rapid rise; that of bear No. 2 remained stable. In bears Nos. 1 and 4 the temperature rose; in bear No. 2 it remained constant; in bear No. 3 it continued to decline. The pulse of bears Nos. 1, 3, and 4 rose quite rapidly, while that of bear No. 2 declined. Variation of individual reaction was probably due to slight differences in the dosage rate and physiological characteristics of the individuals.

Received for publication August 5, 1958.

OBITUARIES

H. S. DAVIS

1875–1958

Dr. Herbert Spencer Davis, who might be said to have been the "Dean" of American Fish Culturists, passed away in Orlando, Florida, on July 15, 1958, at the age of 83. His birthplace was Oneida, New York. He authored numerous papers dealing with parasites and diseases of fishes and was best known for his *Care and Diseases of Trout* (1934) and *Culture and Diseases of Game Fishes* (1953).

After taking the degrees of B.S. and Ph.B. at Wesleyan University, he secured his doctorate at Harvard. He taught from 1901 to 1906 at the State College of Washington and was Professor of Zoology at the University of Florida from 1907 to 1922. He joined the staff of the former United States Bureau of Fisheries (now Fish and Wildlife Service) in 1922 and remained in federal-government service until his retirement in 1944.

As Chief of Aquicultural Investigations of the U.S. Bureau of Fisheries, he instituted many of the earlier stream and lake surveys conducted by A. S. Hazzard, E. W. Surber, T. K. Chamberlain, the writer, and others. He administered the work produced between 1925 and 1944 at the Leetown Experimental Fisheries Station in Virginia, the Pittsford Station in Vermont, and the Convict Creek Experimental Stream in eastern California.

He served as President of the American Fisheries Society in 1932–33 and as Chief Fish Pathologist for the Oregon State Game Commission from 1945 to 1947, after which he became Research Associate in the Zoology Fisheries Division of the University of California at Berkeley, California.

One of the main contributing factors to his widespread influence was his clarity of expression in use of the English language. He had the ability to say precisely what he meant in a simple, clear-cut style, and younger workers would find it profitable to read his papers and books as examples of conciseness and accuracy in the writing of scientific material.

A colleague of Dr. Emmeline Moore and of the late Dr. George C. Embody, John W. Titcomb, and others, his was a long career devoted to unselfish service in the field of fisheries. His early pioneering of on-the-job studies and experiments at producing hatcheries exemplified the vision which led to the many well-equipped fish-cultural research centers of the present time. He contributed many papers dealing with stream and lake surveys and management problems in general, aside from those concerned purely with diseases, nutrition, or parasites of fishes. Some of the first efforts toward breeding superior strains of fish were also initiated by Dr. Davis.

Dr. Davis was a most competent and unassuming person. His friendly, quiet manner, and unfailing good humor were among his strongest assets. Fish hatchery personnel were among his closest friends. After completing *Culture and Diseases of Game Fishes*, he retired to Orlando, Florida, where his special hobby was growing flowers. He is survived by his wife, Mrs. Rayner H. Davis, and by a daughter, Muriel Davis.

Dr. Davis can never be replaced because of the combination of talents he possessed, but some little part of him exists in the many men who trained under him.—PAUL R. NEEDHAM.

GLENN EVERETT MITCHELL

1888–1958

Glenn E. Mitchell passed away in Portland, Oregon, on March 17, 1958.

Glenn was born in De Smet, South Dakota, on July 5, 1888. His family moved to a ranch in Okanogan County, Washington, where his boyhood was spent. He attended high school at Oroville, Washington, and studied forestry at Washington State College for a year.

His first employment with the U.S. Forest Service was in 1909 when he served 3 months as forest guard on the Okanogan National Forest. He was appointed forest ranger on July 1, 1911, and stationed at Pateros, Washington. On July 1, 1918, he was promoted to deputy forest supervisor with headquarters at Okanogan. From 1930 to 1931 he was supervisor of the Colville National Forest at Republic, Washington. In 1932 he transferred to the Siskiyou National Forest at Grants Pass, Oregon. From May 1, 1939, until his retirement from the Forest Service on May 31, 1950, he was in charge of wildlife management activities on the national forests of the Pacific Northwest Region. Following retirement he worked about 4 years as public-relations officer with the game department of the State of Washington.

One of Glenn's early supervisors on the Okanogan forest, H. M. Hale, wrote of him in 1916 as follows: "His personality is unusually attractive, and he has a wider acquaintance and is more favorably known than any other man on the force. His dealings with the public are most satisfactory, largely due to a sympathetic nature and a sunny personality." At the end of his career of over 40 years as a public servant, Glenn's long-time friends, as well as later associates, were still remembering these traits in him. Vernon V. Harphan states: "When Glenn Mitchell passed away, the Forest Service lost a good friend. Likewise, those of us who knew Mitch most intimately realize that we have lost a good personal friend. I worked, played, and batched with Mitch in the good old Okanogan days of 1911–1915. He made friends for himself and certainly for the Forest Service wherever he went or worked. He was intensely loyal and straightforward about his official work, and built many monuments that will long be remembered."

Mitchell generously shared with his associates the knowledge and experience gained from a lifetime of work in the out-of-doors. If one of his ideas or suggestions resulted in worth-while accomplishment, he was happy with the result without seeking credit or honor for himself.

Glenn was a real horseman, and some of his fondest recollections were of the years spent in the forests when travel by horseback was the rule.

The Mitchell family was widely known in the Okanogan country, where a sister, Mrs. Mildred Sexson, still resides. Other survivors are his wife, Alice; a son, Glenn A., San Francisco; two daughters, Ruth M. Dole, Portland, and E. Loreen Hansen, Riverside, California, and six grandchildren. —J. HERBERT STONE.

BOOK REVIEWS

Living Resources of the Sea. By Lionel A. Walford. The Roland Press Company, New York. 1958. xv+321pp., 23 maps. $6.00.

The author's aims are better expressed in the subtitle of his book, which is, "Opportunities for Research and Expansion." The study was made at the request of The Conservation Foundation, on whose behalf Dr. Walford undertook ". . . to determine how the harvest of the sea fisheries could be substantially increased for the benefit of humanity," to quote from his Preface. He gives his study world-wide scope because, as he says, "Human food needs are world-wide."

In effect, what Dr. Walford does determine, and this is the oft-recurring theme of his book, is that a great deal more fundamental research must be accomplished before any important increase in the yield from the seas can be achieved.

The book is divided into two uneven parts, the first and larger being titled "The Marine Wilderness," and the second, "The Resources of the Sea." In the first part the author deals with his "problem," which is, to state it briefly, to identify and explore the important gaps in our knowledge of the oceans and what they might yield. In the second part the author discourses in turn on the various kinds of marine organisms which might give the new or greater yield, provided that the proper scientific attention is paid them.

Some idea of how Dr. Walford deals with his subject can be gained by referring briefly to the principal chapters of the first half of the book. "Conservation" is mainly a rather elementary treatment of the mathematical principles employed in determining the effects upon a stock of fish of natural and fishing mortality. The author feels that maximum yield can be achieved only when exploitation is directed in accordance with scientific principles based upon detailed biological information. He concludes that the yields of certain fisheries could be substantially increased by stricter adherence to scientific management. "The Identity of Species" constitutes an argument that the field of taxonomy is being neglected, and that

the ability of those concerned to recognize species in all phases of their variation has an important part to play in realizing greater yields. In the two chapters "Environment" and "The Uses of Ecological Principles," the author develops the theme that because of the complexity of the marine environment, and because of the likelihood of varying degrees of interaction and interdependence between organisms, coordinated research by teams of specialists is required, as well as the systematic observations that must be carried out year after year. In the chapter titled "Behavior," the author urges that the behavior of marine organisms should be studied more extensively, in order that fishing techniques and gear might be improved through observations made upon activity and responses. He recommends the establishment of a special laboratory to study the behavior of marine animals. In "The Dream of Harvesting the Plankton," that topic is given a brief review, and finally the author gives his opinion that the prospects for a convenient and substantial yield of protein from a plankton source are not encouraging. Better prospects, considered in the chapter "Farming the Brackish Waters," are more likely to be realized from the increased utilization of the organically rich inshore waters and estuaries. In fact, Dr. Walford feels that the farming of these regions may be one of the most important means of increasing the production of food from the sea. The chapter "Poison" surveys the occurrence of poisonous marine organisms. The author feels that lack of knowledge in this matter is hindering the fuller utilization of the available resources. This may be especially so in the tropical and subtropical seas, where variation in the marine fauna is greatest, and where scientific knowledge of it is weakest. Research is needed to facilitate identification, to find means of eliminating poisons wherever possible, and to explore their possible medicinal uses. The chapter on fishing vessels and fishing gear reviews the several fields in which improvements have been made or are indicated, and the author recommends the establishment of a special laboratory to test fishing equipment. Dr. Walford also refers to the problem of harmonizing modern innovations with long-established social and economic structures.

In the second part of the book, invertebrates, fishes, reptiles, marine mammals and seaweeds are dealt with in turn, by chapter, with a view to determining the prospects of each group for greater utilization. Squids and mussels are given some prominence among the invertebrates, and the nototheniids and the cyclothones among the fishes —not as presently important products, but as some which may become so eventually. Little is to be expected from any of the reptiles, and it is unlikely that any of the mammals are now being underfished. Although seaweeds may become increasingly valuable in a variety of ways (for fertilizers, textiles, sources of rare chemicals), their low nutrient value will limit their importance as food.

In his final chapter, "Looking Forward," Dr. Walford speculates that under the existing limits of our present state of knowledge of the seas' potentials, "The total world production could increase in the natural course of events only by a factor of something less than two." However, it is probable, he feels, that this could be greatly increased if we did not "limit ourselves to tradition." In other words, we are again brought to "the heart of the problem"—which is, that there must be more fundamental research in all problems relating to the resources of the seas.

A word about the author's method—in general it is to state his argument, and then to support it by many examples drawn from the pertinent scientific literature. At times this makes interesting reading, but, unfortunately, it has also lead the author into being somewhat superficial in his treatment of some topics. Certain life histories and many quotations could have been left out to advantage. The reader is refreshed and encouraged by Dr. Walford's enthusiasm in the cause of marine research and convinced that there is need for much more of it. He is less sure, however, just where one should begin, for, finally, he is made convinced that we know so little, and that there is so much more to learn.

The many notes and references are given, by chapters, at the back of the book, and there is also a good index. The only illustrations are the 33 world maps, which might better have been of a more familiar projection. The author's style is clear and direct, and the text happily free of error.—HAROLD GODFREY, Fisheries Research Board of Canada, Biological Station, Nanaimo, British Columbia.

The Black-tailed Deer of the Chaparral. By Richard D. Taber and Raymond F. Dasmann. State of California, Department of Fish and Game, Game Bulletin No. 8. 1958. 163pp.

The bulletin covers data collected during a 7-year study of Columbian black-tailed deer and their habitat in Lake County, California. The study was supervised by the University of California under a contract from the California Department of Fish and Game. Although the authors point out that they do not have all the answers, this is without question the most comprehensive study of black-tailed deer that has been made to date.

The black and white drawings of Gene Christman, which are used to illustrate the entire text, are an outstanding feature. They are accurate as to detail and exceptionally well done. He has illustrated deer both externally and internally, as well as parasites and various shrubs, with equal facility.

As written, this bulletin appears to be one of the better compromises between a popular and a technical report. The first portion of the report is very smoothly written and easy to read but contains little technical data. This section includes a brief history

of black-tailed deer in California, a description of the study area, follows the life cycle of the deer throughout the year and gives information on management of the range and the deer herd.

The second section of the bulletin consists of ten appendices. Most of the material of interest to a technician will be found in this section. The appendices are not handled in the usual sense but include discussions of techniques and results as well as technical data, making each a complete entity. A listing of the appendix titles will probably give the best idea of the areas covered. These are: Distribution and Abundance of Plants; Food Habits; Quality of Deer Forage; The Plane of Nutrition; Production and Utilization of Forage; Growth, Weight, and Condition; Population Density and Dynamics; Diseases and Parasites; Management Tools and Techniques; and Common and Scientific Names of Plants.

One of the most important points that the authors make is the need for either-sex deer hunting in this area. This need is demonstrated very clearly in the section on population dynamics. Here it is shown that only about 3 deer per square mile are being harvested from a stable population of 90 deer per square mile in shrubland areas and about 1 deer from populations of 35 deer per square mile in chaparral areas. A more realistic harvest from populations such as these would be 10–15 deer per square mile in the shrubland and 3–5 deer in the chaparral.

Many game technicians attempting to manage populations that are being produced as a by-product of other land uses may find themselves somewhat envious of the situation described by the authors. In the area described, the habitat is being manipulated primarily for the production of game with only the limitations necessary for erosion and wildfire control. The merits of mechanical equipment, fire, and chemicals for opening up dense stands of chaparral are discussed and situations where each method is most applicable are pointed out. The benefits derived from this type of range management are clearly shown by comparing deer-population figures for untreated chaparral with areas of shrubland opened up by one of these methods. However, some readers may question whether the cost of this operation can be justified until such time as provisions can be made to harvest adequately the increased production of game.

The few minor criticisms pertain primarily to organization rather than the subject matter. In the introduction, the authors point out that the report is arranged in three parts, but neither the table of contents nor the subject headings indicate such a breakdown. They also state, "The third section is the appendix, where the information on which the first and second sections were based is presented and developed." However, in only three instances is there any reference made in these sections to data in the appendix. The value of the bulletin to the technical reader would be increased if these sections were more closely tied to the data presented in the appendix. Several of the illustrations are not discussed in the text. Most of these are self-explanatory, but some are not. For example, Figure 27 would be more easily understood if the reader were referred to the tables in the appendix from which the illustration was derived.

In Appendix VII (Population Density and Dynamics), the authors describe a method of determining population structure through field classification of deer into five classes—fawns, yearling does, yearling bucks, adult does, and adult bucks. After many attempts along similar lines, I cannot help but question the accuracy of any population structure that includes a field classification of yearlings, particularly yearling does.

These are minor considerations; as a whole, the bulletin is well written. It will be a valuable addition to the library of anyone interested in big-game management. Also, it seems difficult to see how anyone, be he sportsman or administrator, after reading this report, could fail to see the need for adequate deer harvests in this area.—E. READE BROWN, State of Washington Department of Game, Elma, Washington.

History of New Hampshire Game and Furbearers. By Helenette Silver. New Hampshire Fish and Game Department, Concord. Survey Report No. 6. May 1957. xiv+466pp. $2.85.

This history is an important contribution to the understanding of wildlife problems, not only in New Hampshire, but in the Northeast in general. Mrs. Silver has succeeded in making it very interesting to read—not an easy task when much of the data are drawn from early records and local histories. We heartily concur with the Northeastern Section of the Wildlife Society's selection of this work as the region's outstanding publication of 1957.

The *History of New Hampshire Game and Furbearers* is divided into three parts. The first covers "the conditions and alterations of the wildlife environment through the three and a quarter centuries of white man's occupation of the State." The idea that most of the state was originally virgin timber and poor game range is disputed. Natural phenomena such as fires and wind storms kept much of the area in a habitat capable of supporting an abundance of game. The effects of civilization are thoroughly discussed. The "concept that human development, customs, attitudes, and land management practices" are inextricably tied up with the welfare of the wildlife is well brought out.

The last two chapters in Part I are of special interest to wildlife biologists. These cover "Sanctuaries, Refuges, and Management Areas" and "Research and Modern Management." Under the latter chapter all of New Hampshire's P-R projects are summarized in sufficient detail to be of value to other investigators. This type of summary could

well be done by other states, as so much information from P-R work is hidden away in unpublished reports. Unlike some of the publications of various conservation agencies, this chapter reports all work —be it good, bad, or indifferent—and does not restrict itself to that which flatters the Department.

Parts II and III cover the histories of individual species of big and small game, some mammalian predators, furbearers, upland game, shore birds, waterfowl, mourning dove and passenger pigeon. The readability of this chapter varies from species to species. As is to be expected, there is much repetition of material already covered in the first section. The coverage of each species varies greatly, according to the material available. Thus, while the ruffed grouse and white-tailed deer are given very complete treatment, many species of waterfowl and shore birds are allotted only short paragraphs. The list of references is extensive.

There is a need for better understanding of the past status of game as we work toward present and future management. Mrs. Silver has done for New Hampshire an excellent job that could be emulated by other states to great advantage.—BRADFORD E. BROWN, Department of Conservation, New York State College of Agriculture, Cornell University, Ithaca, New York.

The New Way of the Wilderness. By Calvin Rutstrum. The Macmillan Co., New York. 1958. ix+276pp., 85 illus. $4.50.

To those familiar with Mr. Rutstrum's earlier text, *Way of the Wilderness,* the title of his latest book is self-explanatory—a new and up-to-date treatment of wilderness travel and related camping procedures. This book has been written principally to provide the information necessary so that an amateur may embark on a wilderness adventure with the proper equipment and with a backlog of basic camping "know-how." Here is the short-cut for the novice from a man whose practical wilderness experience cannot be questioned. In the same breath, there are many tips for the experienced woodsman. Time and again this reviewer came across camping techniques that he had thought one could learn only from experience—simple little tricks, but so often overlooked in other camping manuals. This book also differs from many of the standard woodcraft volumes, which are almost encyclopedic in scope, in that it only includes those techniques and provisions that Mr. Rutstrum has personally adopted or will recommend after extensive experimenting or testing in the field. It takes several trips to build a proper outfit. The beginner will find that some of the suggested items (pp.171–181) will be difficult to locate and may have to be specially made, for example, the all-weather tent (p.112).

The first chapter, "The Wilderness Challenge," is intended to stimulate interest in wilderness travel. Emphasis is placed on the necessary training and values to be derived from wilderness experiences. It is pointed out that guides can be valuable teachers but, when they are taken along solely as work horses, much of the value of outdoor living is missed.

Chapter 3, "Canoe Travel and Procedures," includes such subheadings as: canoe stability, being windbound, rapids, poling, portaging, canoe repairs, and canoe strokes. The author suggests on page 18 that, if you have a long distance to travel down a river, two canoes can be lashed together and a tent pitched on a platform between the canoes. "You can travel 24 hours a day in shifts." The reviewer cannot think of any wilderness waterways that he has navigated in which he would rest easily on a platform between two canoes drifting downstream at night. Ten canoe strokes are well illustrated with both a sketch of a man executing the stroke and an overhead diagram depicting the path of the paddle in completing the movement. Of considerable interest is the description of the pitch stroke commonly used by many canoeists but not previously described in canoeing texts.

Some of the information presented in Chapter 4, "Pack Horse Methods," is neither clearly nor adequately covered. Perhaps the author realizes this, since he indicates that an outfitter will have to be relied on for pack-horse trips. The 324-word confusing description of the diamond hitch would have been better omitted.

The backbone of the book is Chapter 8, "Wilderness Camping and Equipment" (53 pages), which begins: "Each item of camping equipment should be judged by its weight, by its adaptability to a wide range of weather and for its practical use. Above all, it must not retard mobility." Mr. Rutstrum is neither a traditionalist (who still clings to the bough bed and canvas canoe rather than change over to the air mattress and aluminum canoe) nor a "go-light" enthusiast whose answer to wilderness travel is a blanket and an axe. The author's lists of equipment are well balanced, weight versus comfort, and completely modern. Excellent sections on tent models, axemanship, food containers, and bedding are presented here. The reviewer would like to have known the weights of Rutstrum's two tent models. The discussion of camera equipment and procedures is inadequate; reference could have been made to some of the good texts on the subject.

Chapter 13, "Wilderness Recipes and Menus," including some 98 receipes, is the most appropriate such list the reviewer has seen and will necessitate that the book be included in your kettle pack on the next trip.

The last chapter, on survival, stresses emotional stability and adaptability rather than dwelling solely on the procurement of the necessities for continued existence. The all-important decision, whether to stay where you are or try and walk out, is realistically treated and left to the individual's discretion when he evaluates his situation.

Other chapters not mentioned previously include: "Carrying the Pack Afoot," "Winter Travel by Dog Team and Hand Toboggan," "Go-Light Auto Camp-

ing," "Where Am I," "Clothing and Personal Equipment," "Wilderness Cooking," and "Fishing for Food and Hunting for Food."

The book is a definite contribution to the applied techniques of successful wilderness living. The informal style of writing, with its liberal use of bush slang, reads easily; sections are short and well illustrated. There is no doubt, as Col. Whelen states in the foreword, "Rutstrum savvies the bush ...." Whether you go by raft, dog team, or canoe, this book will see you well on your way.—A. T. BERGERUD, Newfoundland Department of Mines and Resources, St. John's, Nfld.

A Field Guide to Reptiles and Amphibians of the United States and Canada East of the 100th Meridian. By Roger Conant. Illustrated by Isabelle Hunt Conant. Houghton Mifflin Co., Boston. 1958. xv+366pp., 40 plates (24 colored), 62 figs. (exclusive of end papers), 248 distribution maps. $3.95.

This attractive little book, patterned after Peterson's *A Field Guide to the Birds,* is divided into somewhat similar sections. After an Editor's Note and the Acknowledgments, there is an introductory chapter of 10 pages in which the aim and general uses of the book are discussed. This is followed by short chapters on catching and transporting amphibians and reptiles, their care in captivity, and the snake bite problem, with one page of text and one plate of half-tone illustrations on the first-aid treatment of snake bite. The species accounts with their associated plates of black and white and hand-colored photographs make up the body of the book. They are followed by a brief glossary, a bibliography, 248 distribution maps, and an index.

The species accounts include the common name, scientific name, a brief paragraph of identifying characteristics, usually a sentence or two about habitat, and statements concerning similar species (and/or subspecies), and the range. These meticulously prepared species accounts, together with the magnificent illustrations, make this book, as the publisher's statement on the jacket says, "the most complete, authoritative, and up-to-date guide to reptiles and amphibians of eastern North America yet published." I am certain that it will remain so for many years yet to come.

I do not know of any other two people who could have prepared a book that did so admirably just what this book is designed to do—that is, help in the identification of living reptiles and amphibians of eastern North America. Mr. Conant's wide field experience with the forms in life, his critical eye that lets him see valuable diagnostic traits, and his apparently inexhaustible patience in checking details, combined to make a text that is a fitting matrix for the superb illustrations prepared by his wife, Isabelle Conant. Those of us who know the herpetological writings of Roger and the nature photography of Isabelle were expecting this to be an outstanding job, and we have not been disappointed. It is always difficult for the experienced to appreciate the difficulties of the inexperienced, but I sincerely believe that even the veriest neophyte will find but little difficulty in using this book to learn the herptiles. I am certain, also, that the "professionals" will want to keep their copies handy, for where else will they find the same material so well synthesized and illustrated?

Any book is likely to have errors of both omission and commission. The former are matters of opinion, of course, but I note two that seem to me to be of importance. I think that somewhere there should have been a definition of a reptile and an amphibian. My other suggestion would be for the publishers of such books to supply waterproof plastic jackets with them. That would mean that they could be used without damage by someone holding a wet frog and that they would be better protected while being carried about in the glove compartment of the car, a knapsack, or a jacket pocket as the editor suggests.

Errors of commission are apparently quite rare—I noted but one minor one in the text on my first perusal. I would like to suggest that those who find them notify the Conants so that they may rectify them before the second printing. A few of the colored illustrations seem to have suffered a little in reproduction, but the user should be certain that the illustration is not within the range of variability of the species before he becomes too critical.

This book should be in the library of everyone concerned with a knowledge of the vertebrate fauna of eastern North America. No other can fully take its place.—COLEMAN J. GOIN, University of Florida, Gainesville, Florida.

The Ring-necked Duck in the Northeast. By Howard L. Mendall. University of Maine Bulletin, Vol. LX, no. 16. 1958. xv+317pp., illus. $2.50.

With the addition of a foreword which I am sure many distinguished conservationists would have been happy to contribute, a dedication page, and minus the advertising, this publication would have made a handsome, hard-covered, across-the-counter sales item. As such, it might have reached more sportsmen. It is the kind of book Mr. Average Hunter would comprehend and appreciate—and which he needs in order to understand what is being done for both the hunter and the ducks. I hasten to add that had Mr. Mendall published his material on butcher's paper, it would not have detracted from the high quality of the research and presentation throughout.

The bulletin is divided into 14 chapters that generally follow a seasonal chronology. The text is supplemented with 16 clear figures, 24 plates of two illustrations each, 24 tables, and 10 appendices plus several summarizing text tables. Included is a three-page index. All of the graphic aids are ex-

cellent, although a photo of dead ducks and a shotgun does nothing for me. The bill ring on the specimens in Plate 1 looked painted in.

In the first half of the bulletin, the author occasionally eases into literary prose complete with descriptive euphony. Although one is at first unprepared for this in a scientific bulletin, the effect is good and in keeping with the expository material that follows. This style fades in the last half of the book and, although I was prepared for and would like to have seen an epilogue, none was presented.

Each chapter has a concise summary that will make the book easy to understand and digest. A large section (pp. 45–143) deals with the activities of the breeding season. Except for the material on behavior which seemed somewhat labored, this is indeed a model field study of a waterfowl species. The effort spans 13 years (1943–55) and covers all major phases of ring-necked duck biology. Documentation of even the relatively minor aspects is outstanding. For example: Records of the incubation hours of the female during given days were sufficient to plot an "on the nest" curve for the daylight hours (Fig. 9).

A commendable aspect of this report is the continuous high quality of field research. I was also impressed with the fact that the writer and his colleagues wasted no time in undertaking a full-scale investigation of a new member of the northeastern avifauna. Although the ring-necked duck has long been considered a native western and midwestern species, no research has been geared there to investigating the ecology of this duck.

The numerous tables are lacking in statistical treatment. An occasional standard-error calculation would have helped. On the whole, however, the data are so overwhelming and claims made for them are so moderate that one does not feel a need for statistical analysis in this report.

Chapter 14, on management, testifies that this is more than a life-history study. All phases of management were investigated. After each is appraised, the author concludes: "I believe that the most important single procedure in waterfowl management in the Northeast is adequate control of water levels." This could be claimed for all waterfowl everywhere. However, the writer has carried on research to show exactly how water-level control affects ring-necked ducks (and black ducks). Optimum breeding conditions on his experimental areas were dependent on a control of levels within a range of 6 in. (p. 240). Refuges are needed only for the nesting season, artificial propagation is not feasible and general predator control is not recommended.

I was amused at the author's insistence that the ring-necked duck is wary, and might have let the idea pass but for the statement that "They are almost as wary as black ducks." Adding my own experiences with those of a small sample of midwest hunters, I would say that, except for the hooded merganser and possibly the bufflehead, the ring-necked duck is the least wary of all waterfowl.

The Achilles heel, if there is one in this work, is that the author shifts from the vague passive voice, e.g. "it was noted" or "it has long been known" to the direct and desirable active voice, e.g. "I have observed" or "I do not believe."

The bibliography contains 219 titles. I found only two short papers dealing with the ring-necked duck that were not used. Both were in somewhat obscure sources. The section on Acknowledgments is monumental. I know of no other book that gives greater care to detailed acknowledgments of help received. One can only think highly of an author who meets this obligation more than half way.

In my opinion, this is an outstanding contribution to wildlife management and will serve as a model in long-term field research. My recommendation: Get a copy before the supply is exhausted.—ROBERT A. MCCABE, Department of Forestry and Wildlife Management, The University of Wisconsin, Madison 6, Wisconsin.

Birds of the Ungava Peninsula. By Francis Harper. University of Kansas Museum of Natural History, Miscellaneous Publication No. 17. 1958. 171pp. 6 plates, 26 figs. Copies (paper, $2.00) may be obtained from The Arctic Institute of North America, 1530 P Street NW, Washington 5, D.C.

For ornithologists to whom field study is the *raison d'être* and library work a chore, Francis Harper's book will be a life-long friend. Although his own studies are limited to one summer, the author has done such a thorough job of tracking down records from the interior of Ungava (he says that the region is "an all but unknown land to biologists," yet his literature citations number almost 200 items) that it will be many years before the task needs to be done again. Apparently, an even more exhaustive treatment of coastal areas is being prepared by W. E. C. Todd. The only previous comprehensive review was published in 1907.

The Ungava Peninsula, as defined by Harper, extends 1,000 miles from Cape Wolstenholm in the north to Lake St. John in the south, and an equal distance from the east coast of Hudson Bay to the Atlantic Ocean. While the book is more useful because of this extensive coverage, unity of thought suffers as a consequence. The region may be geographically distinct (although the southwestern limits are somewhat arbitrary), but it is obviously not a faunistic entity. For example, it is disconcerting to try to visualize the habitat of great blue herons or gannets, when their near neighbors in the annotated list of species are the red-throated loon and American eider. Similarly, the American (water) pipit and magnolia warbler would seem to have only remote ecological or geographical relationships to each other. A list (p. 27) in which 84 species of birds are allocated to life-zones is of considerable help in that connection.

The author has been able to include material in this publication that would have been omitted from

an ordinary journal paper. For example, he discusses the contributions and personality of Henry Connolly (former officer of Hudson's Bay Company) for nearly two pages, only slightly less space than is given to physiography and vegetation (the author plans further papers on vegetation, climate, and related matters which, it is hoped, will appear shortly). Mr. Harper also devotes a considerable amount of space to Indian and French names of birds and to descriptions of song variations which, unfortunately, do not have the same meaning to the reader that they do to the author.

Of the 12 photographs, six are well-chosen pictures of vegetation, and one is a fine view of a male spruce grouse in courtship display. In my opinion, the other photographs could have been replaced by more informative ones. The 24 distribution maps are of considerable value; one might wish, however, that space had permitted detailed maps covering a larger number of birds. The author does not include a master map on which place-names are printed; such a map would have been extremely useful to most readers. Some, but not all, of the places mentioned by Harper are listed in the introductory section, along with latitude, longitude, and approximate elevation.

If this publication had done nothing else, it would have earned a place in the library of ornithologists by demonstrating the existence of a truly wild region just over the back fence from the most densely populated areas of the United States and Canada, where a biologist must name lakes to keep his field notes in order, and where, in an area of nearly a million square miles, there are fewer residents than in a small New England city. The challenge of unsolved problems is there, too: What is the significance of summer aggregations of male white-winged scoters and American goldeneyes on the coasts of the Ungava Peninsula? Where do snow geese cross Ungava on their northward flight? What complex of factors limits the abundance of the common loon and osprey in this region? Does the least sandpiper breed in the interior of Ungava? What kind (or kinds) of Hudsonian chickadees are found in this vast area? The answers to these and many other questions are still locked in the heart of the Ungava wilderness, and it is a fortunate biologist who will have the opportunity to find them.
—ROBERT B. WEEDEN, Department of Zoology, State College of Washington, Pullman, Washington.

Comparative Biosystematics and Life History of the Nuthatches Sitta pygmaea and Sitta pusilla. By Robert A. Norris. University of California Publications in Zoology, 56(2):119–300. 13 figs. 1958. $3.50.

What is a species? A few years ago the essence of the answer given by many biologists would have been "a group of organisms attaining a certain degree of morphological distinctness." The practicality of that definition was never very great, as each biologist had different criteria for the "certain degree" of difference, and its theoretical basis has long been questioned. Modern systematics has not solved the species problem, but the scope of its inquiry has widened far beyond the typological or morphological concept. Perhaps no other single publication in ornithology has demonstrated this fact so conclusively as Robert Norris' *Comparative Biosystematics and Life History of the Nuthatches Sitta pygmaea and Sitta pusilla.*

The objectives of the study are threefold: (1) to present the biological characteristics of two closely related, allopatric forms of nuthatches; (2) to compare the birds with respect to the characters studied; and (3) to show whether the two forms are full species or subspecies. In four years of research in Georgia and California, the author obtained and evaluated data on a remarkably wide range of subjects, from taxonomy to population characteristics, and from the incidence of song "duets" to degree of parental care. The publication also includes material on skeletal features, incidence of threesomes, sex ratio, territory, nest sites, nests, eggs, incubation, hatching and development, weights, molts, foods and foraging, predators, parasites, breeding seasons, and roosting. Obviously, it was impossible to treat each subject equally. Occasionally, the author made comparisons on very little information, especially in certain behavioral aspects of life history. For example, the comparison of hole-excavation methods is based on one detailed observation of the pigmy nuthatch (*Sitta pygmaea*) and several shorter observations of brown-headed nuthatches. Similarly, predation and parasitism are discussed on the basis of a rather small amount of data. However, the analyses of such important subjects as plumage, skeletal features, nest sites, and song are founded on substantial information.

Just as it was not feasible to study each aspect of biology with the same intensity, it is impossible to attach the same degree of importance to the differences described. To what extent do differences in territory size, for example, reflect a genetic gap, and to what extent are they the result of different ecological situations in the range of the two nuthatches? What meaning can be ascribed to deviations in foods and foraging, nest materials, and interactions with other species? The decisions are necessarily subjective, and it is to the author's credit that he has presented all of the pertinent data, to allow the reader to weigh the facts in this book for himself.

Dr. Norris has done an admirable job of presenting his case in clear, concise form through careful writing in the text and through the use of excellent comparative summaries at the end of each section. Thirty-six tables and 13 figures facilitate examination of the data. His conclusion that the two nuthatches are full species is based mainly on distinctions found in plumage, skulls, songs, height of nests, egg color, parasites, organ weight/body weight ratios, breeding seasons, roosting, territory

size, and a group of observations related to metabolic rate.

In discussing the status of allopatric forms in his brief introduction, the author states that ". . . in the absence of experimental analysis under suitable conditions, it is almost impossible to prove for such populations either conspecificity or specific distinctness." In his summary, the author concludes that "These findings—morphologic, ecologic, and ethologic—lead me to predict with confidence that if the two nuthatches were to meet as contiguous or sympatric populations, they would neither hybridize successfully nor even interbreed." The final step seems clear—try it, and see!—ROBERT B. WEEDEN, Department of Zoology, The State College of Washington, Pullman, Washington.

Man's Role in Changing the Face of the Earth. Edited by William L. Thomas, Jr. The University of Chicago Press, Inc., Chicago. 1956. xxxviii+1,193pp., 180 illus. $12.50.

" 'Man's Role in Changing the Face of the Earth' is many things. It is part of the historical reality of the earth during its latest phase, which has witnessed the presence of man. It is an idea or theme of which man, conscious of himself and his activities, has become increasingly aware and which has been touched upon in one or another aspect by scores of scholars through the ages. It was an international symposium, organized by the Wenner-Gren Foundation for Anthropological Research. . . . And, lastly, it is this volume, which treats all the above through the writings of fifty-three contributors and a report of the Symposium discussions of the seventy participants."

With those words, Dr. William L. Thomas, Jr., introduces the most fascinating, encyclopedic volume on man and his earth that has ever been written. It is impossible for me to review this book with the thoroughness it deserves; I confess that I have not even read all of the articles in it, much less digested its contents. The sole purpose of the present review is to point out the existence of the work and, briefly, to outline its scope and manner of presentation.

This massive, well-illustrated, and surprisingly inexpensive book is composed of three major divisions: Retrospect, Process, and Prospect. Part I (Retrospect) contains 18 papers on two general themes—"Man's Tenure of the Earth" and "Through the Corridors of Time." Like the rest of *Man's Role* . . . , it has a solidly international flavor—a distinctly refreshing approach to those of us who, unfortunately, rarely extend our serious thoughts beyond North America. In Process (Part II) we see the means through which men have altered the waters, climate, soils, atmosphere, and biotic communities of the earth. It is an eye-opening experience to see how modern plant and animal ecology (as represented by the excellent papers of John T. Curtis, F. Fraser Darling, and others) fits into the broad mosaic of this volume. Part III (Prospect) is an attempt to show the limits of man on earth and to predict the impact of his past and present actions on future generations.

In this book are integrated facts on a remarkable range of subjects. In it are fancies, too—for it is unlikely that all of the interpretations put forth are correct (but I am less capable of separating the full truths from the half-truths than those who suggested them). And finally, there may lie in these pages the seeds of ideas that will one day enable us to develop and practice a land ethic based on stewardship and a human ethic founded on sympathetic awareness.

Man's Role in Changing the Face of the Earth is not a book to be read lightly or swiftly. It is one that should be studied, discussed, and absorbed in small doses. If I may be allowed one suggestion, it is this: Do not try to read it from beginning to end. First, travel with E. A. Gutkind over the changing face of our earth and observe the pockmarks of civilization thereon. Then turn to the summary remarks of Lewis Mumford and read them carefully. If you are not amazed, shaken and stimulated, then you have been asleep.—ROBERT B. WEEDEN, Department of Zoology, The State College of Washington, Pullman, Washington.

Audubon Western Bird Guide. By Richard H. Pough. Doubleday & Company, Inc., Garden City, New York. 1957. xxxvi+316pp., 32 color plates, many text figs. $4.95.

This field guide covers all 614 species of birds recorded for western North America, from the Arctic Ocean to Mexico. It is designed to be used with previously published Audubon bird guides for eastern North America: *Small Land Birds* and *Water Bird Guide.* Those species not covered in these earlier volumes are treated in considerable detail, with notes on identification, habits, voice, nest, and range. Western birds that also occur in the East are only briefly listed with a statement of the ranges. This greatly reduces the usefulness of the present volume.

An unusual feature is the coverage of far northern species, such as the yellow wagtail, wheatear, bluethroat, and others that nest in Arctic America and migrate across the Bering Sea to winter in Asia and Africa. The black and white drawings by T. M. Shortt and color plates by Don Eckelberry are of exceptionally high quality. About 220 species are shown in color. The scientific and common names conform to the latest (5th) edition of the American Ornithologists' Union checklist. In spite of the incomplete treatment of species, this attractive book will be of great value to bird students in western North America.—GEORGE E. HUDSON, Department of Zoology, The State College of Washington, Pullman, Washington.

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